US006243446B1

(12) **United States Patent**
Goodman

(10) **Patent No.: US 6,243,446 B1**
(45) **Date of Patent: *Jun. 5, 2001**

(54) **DISTRIBUTED SPLITTER FOR DATA TRANSMISSION OVER TWISTED WIRE PAIRS**

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(73) Assignees: **Inline Connections Corporation**, Arlington, VA (US); **CAIS, Inc.**, Washington, DC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/362,180**

(22) Filed: **Jul. 27, 1999**

Related U.S. Application Data

(63) Continuation of application No. 08/814,837, filed on Mar. 11, 1997, now Pat. No. 5,844,596.

(51) **Int. Cl.**[7] **H04M 11/00**
(52) **U.S. Cl.** **379/93.01**; 379/90.01
(58) **Field of Search** 379/90.01, 102.01–102.03, 379/93.17, 93.26, 93.28, 93.37, 93.01; 348/14–16, 734, 7

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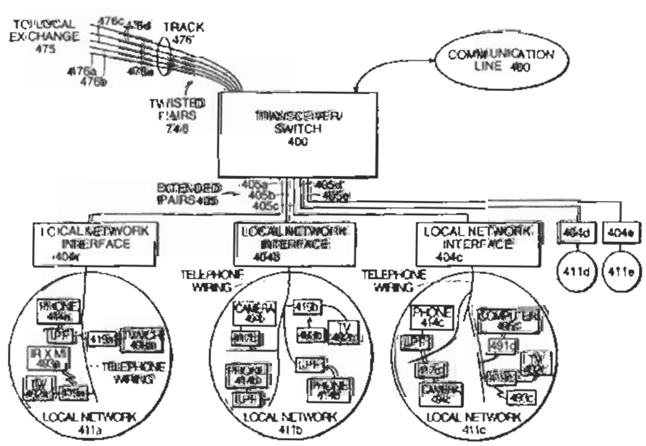
Primary Examiner—Wing F. Chan
(74) *Attorney, Agent, or Firm*—Fish & Richardson PC

(57) **ABSTRACT**

A system that provides video signal communication between a source of the video signal and a plurality of units that include destinations of the video signal includes an interface coupled to the source and to telephone lines, each of which serves at least one of the units and carries voice signals to and from one or more telephones coupled to the telephone line at said unit. The interface receives the video signal from the source, and transmits the received video signal onto at least one of the telephone lines in a selected frequency range that is different from frequencies at which the voice signals are carried on that telephone line. This causes the video signal to be coupled to a receiver which is connected to the telephone line at the unit served by that line and is adapted to recover the video signal from the telephone line and apply it to one or more of the destinations at the unit. The source is a cable (e.g., electrical or fiber optic) that is linked to the interface and that carries a plurality of video signals. The destinations are, e.g., televisions. The units can be residences (such as individual houses or apartments in an apartment building) or offices in an office building.

6 Claims, 25 Drawing Sheets



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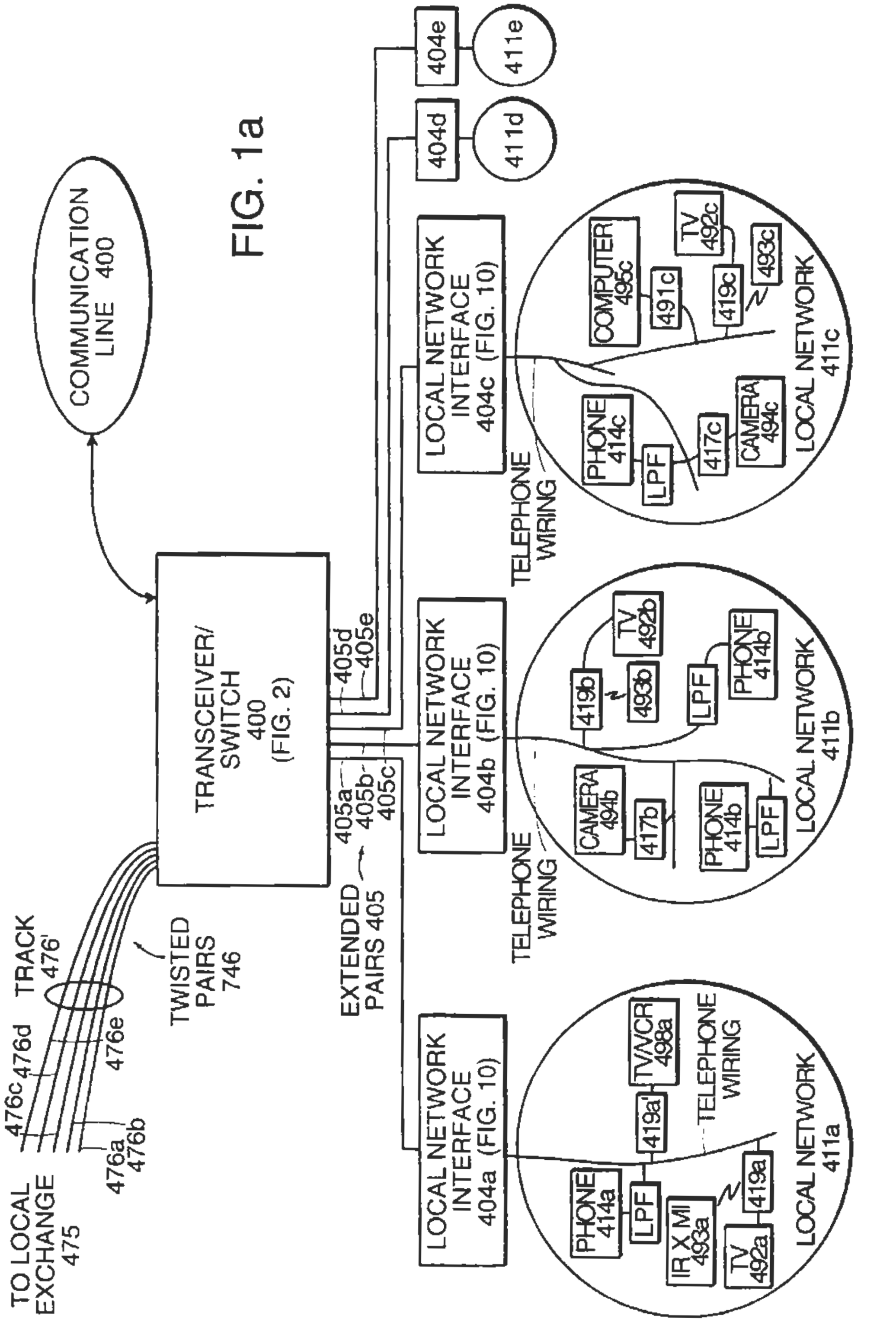

COMMUNICATION LINE 400
TRANSCEIVER/ SWITCH 400 (FIG. 2)
TO LOCAL EXCHANGE 475
476a
476b
476c
476d
476e
TRACK 476'
TWISTED PAIRS 746
EXTENDED PAIRS 405
405a
405b
405c
405d
405e
LOCAL NETWORK INTERFACE 404a (FIG. 10)
LOCAL NETWORK INTERFACE 404b (FIG. 10)
LOCAL NETWORK INTERFACE 404c (FIG. 10)
404d
404e
411d
411e
PHONE 414a
LPF
IR X MI 493a
TV 492a
419a
419a'
TV/VCR 498a
TELEPHONE WIRING
LOCAL NETWORK 411a
CAMERA 494b
417b
PHONE 414b
LPF
419b
493b
TV 492b
LPF
PHONE 414b
LOCAL NETWORK 411b
TELEPHONE WIRING
PHONE 414c
LPF
417c
CAMERA 494c
COMPUTER 495c
491c
419c
TV 492c
493c
LOCAL NETWORK 411c
TELEPHONE WIRING

FIG. 1a

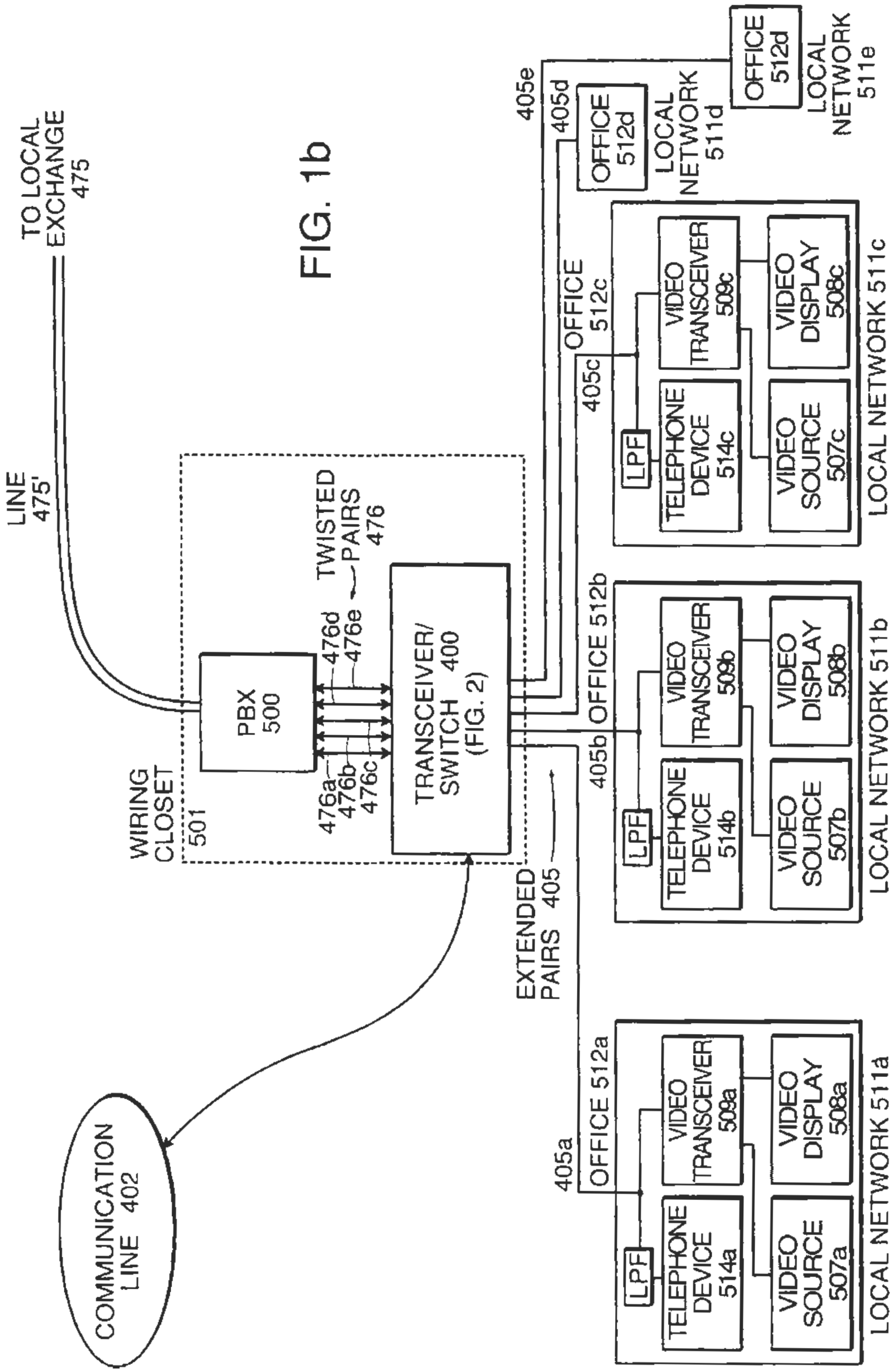

TO LOCAL EXCHANGE 475
LINE 475'
WIRING CLOSET 501
PBX 500
476a
476b
476c
476d
476e
TWISTED PAIRS 476
TRANSCEIVER/ SWITCH 400 (FIG. 2)
EXTENDED PAIRS 405
COMMUNICATION LINE 402
405a
405b
405c
405d
405e
OFFICE 512a
OFFICE 512b
OFFICE 512c
OFFICE 512d
OFFICE 512d
LPF
TELEPHONE DEVICE 514a
VIDEO TRANSCEIVER 509a
VIDEO SOURCE 507a
VIDEO DISPLAY 508a
LOCAL NETWORK 511a
TELEPHONE DEVICE 514b
VIDEO TRANSCEIVER 509b
VIDEO SOURCE 507b
VIDEO DISPLAY 508b
LOCAL NETWORK 511b
TELEPHONE DEVICE 514c
VIDEO TRANSCEIVER 509c
VIDEO SOURCE 507c
VIDEO DISPLAY 508c
LOCAL NETWORK 511c
LOCAL NETWORK 511d
LOCAL NETWORK 511e

FIG. 1b

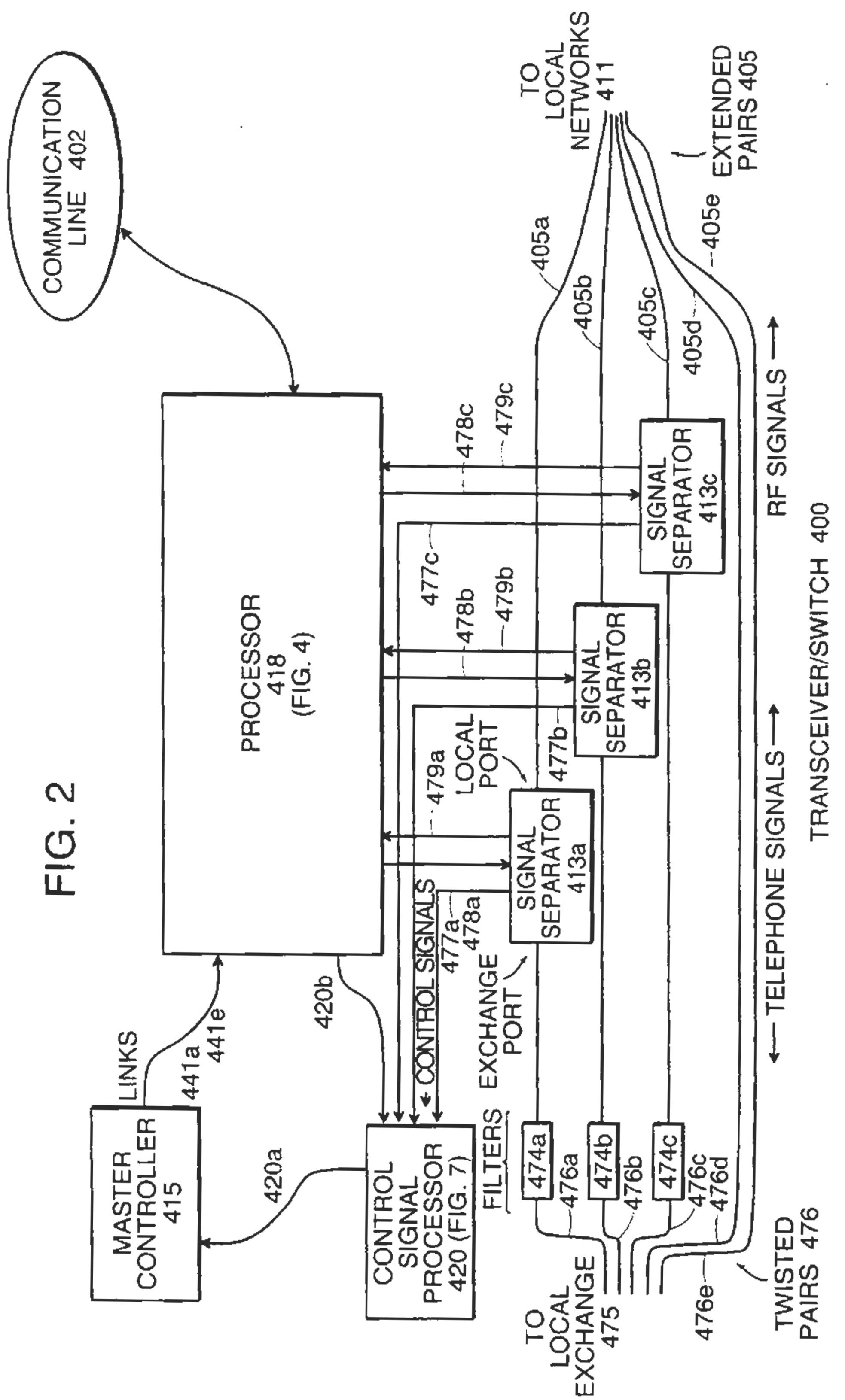
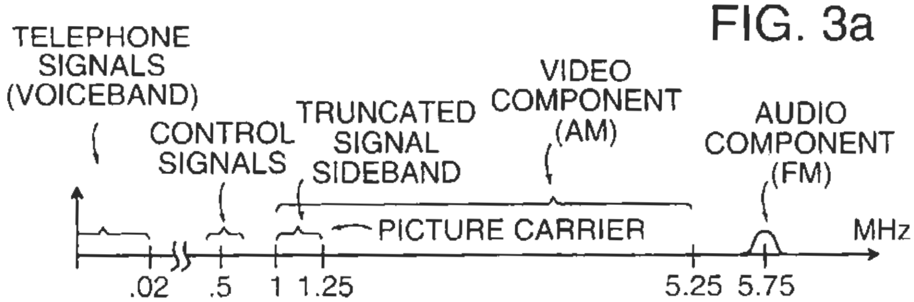

COMMUNICATION LINE 402
PROCESSOR 418 (FIG. 4)
MASTER CONTROLLER 415
LINKS
441a
441e
420a
420b
CONTROL SIGNAL PROCESSOR 420 (FIG. 7)
CONTROL SIGNALS
SIGNAL SEPARATOR 413a
SIGNAL SEPARATOR 413b
SIGNAL SEPARATOR 413c
LOCAL PORT
EXCHANGE PORT
FILTERS
474a
474b
474c
476a
476b
476c
476d
476e
477a
477b
477c
478a
478b
478c
479a
479b
479c
405a
405b
405c
405d
405e
TO LOCAL NETWORKS 411
EXTENDED PAIRS 405
TO LOCAL EXCHANGE 475
TWISTED PAIRS 476
TELEPHONE SIGNALS
RF SIGNALS
TRANSCEIVER/SWITCH 400

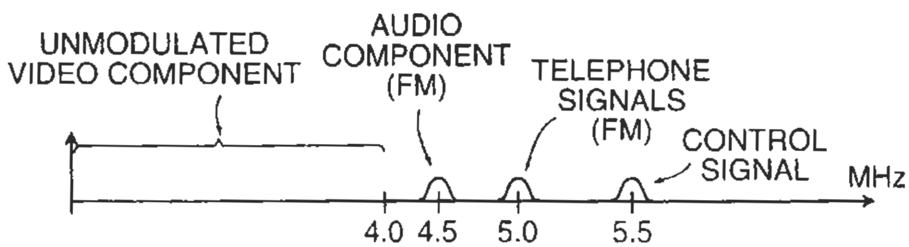
FIG. 2

FIG. 3a



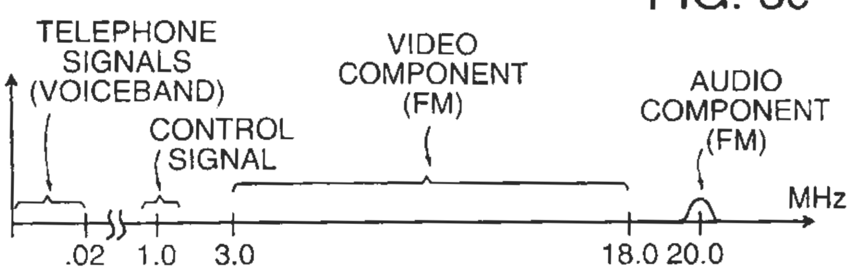
SPECTRUM OF AN AMPLITUDE MODULATED NTSC SIGNAL NEAR VOICEBAND

FIG. 3b



SPECTRUM OF AN NTSC SIGNAL TRANSMITTING AT BASEBAND

FIG. 3c



SPECTRUM OF AN FM NTSC SIGNAL NEAR VOICEBAND

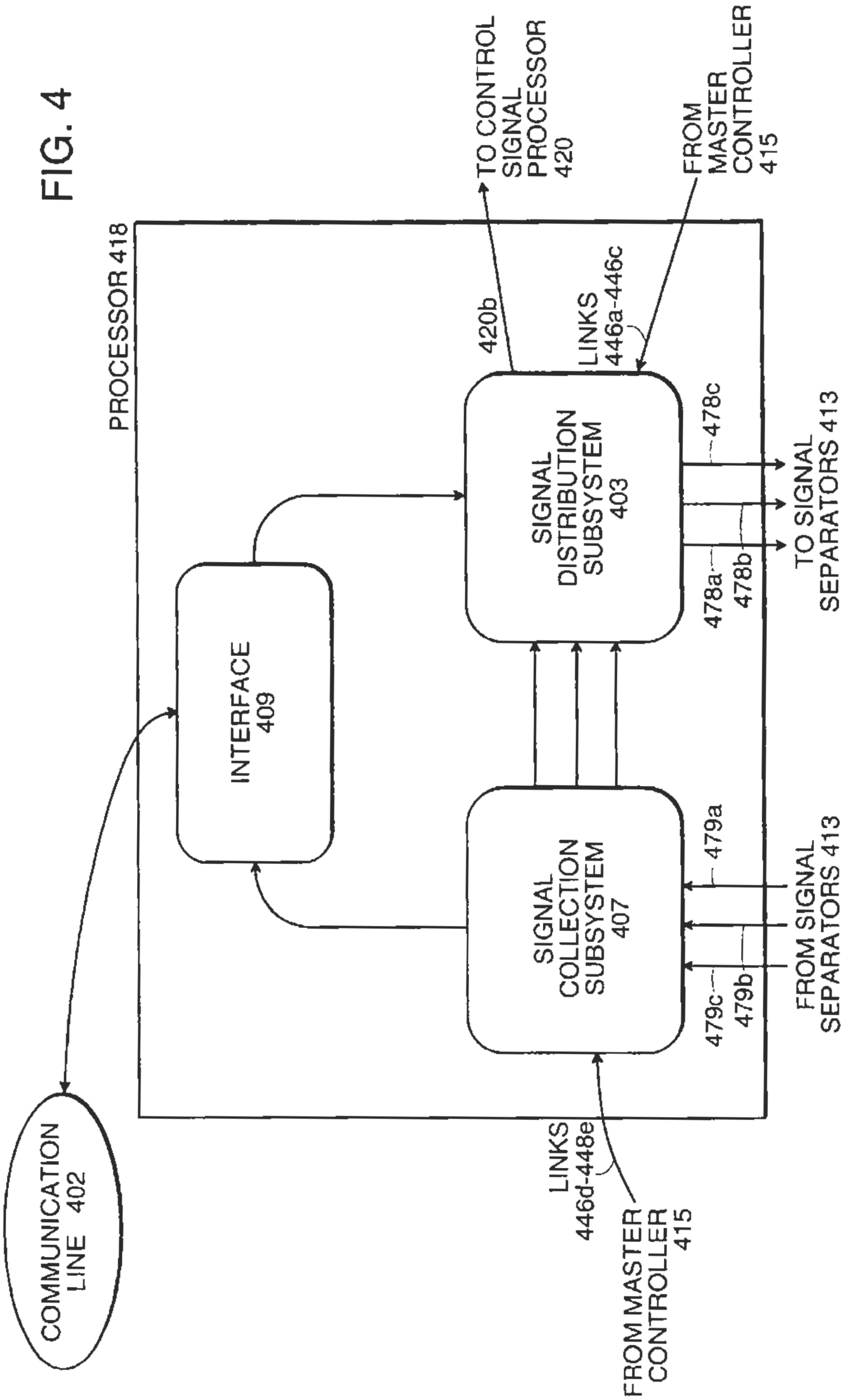

PROCESSOR 418
TO CONTROL SIGNAL PROCESSOR 420
FROM MASTER CONTROLLER 415
420b
LINKS 446a-446c
SIGNAL DISTRIBUTION SUBSYSTEM 403
478c
478a
478b
TO SIGNAL SEPARATORS 413
INTERFACE 409
SIGNAL COLLECTION SUBSYSTEM 407
479a
479c
479b
FROM SIGNAL SEPARATORS 413
COMMUNICATION LINE 402
LINKS 446d-448e
FROM MASTER CONTROLLER 415

FIG. 4

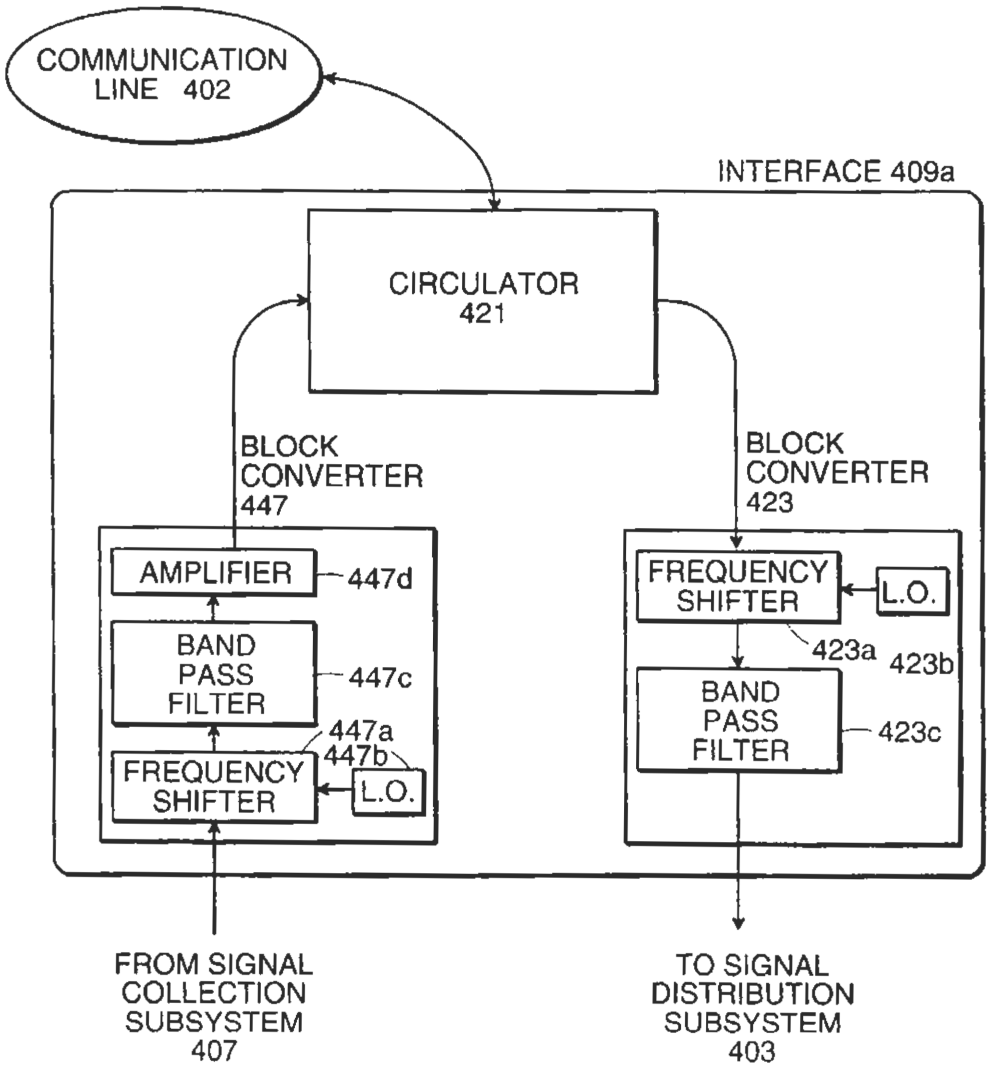

COMMUNICATION LINE 402
INTERFACE 409a
CIRCULATOR 421
BLOCK CONVERTER 447
BLOCK CONVERTER 423
AMPLIFIER
447d
BAND PASS FILTER
447c
447a
447b
FREQUENCY SHIFTER
L.O.
FREQUENCY SHIFTER
L.O.
423a
423b
BAND PASS FILTER
423c
FROM SIGNAL COLLECTION SUBSYSTEM 407
TO SIGNAL DISTRIBUTION SUBSYSTEM 403

FIG. 4a

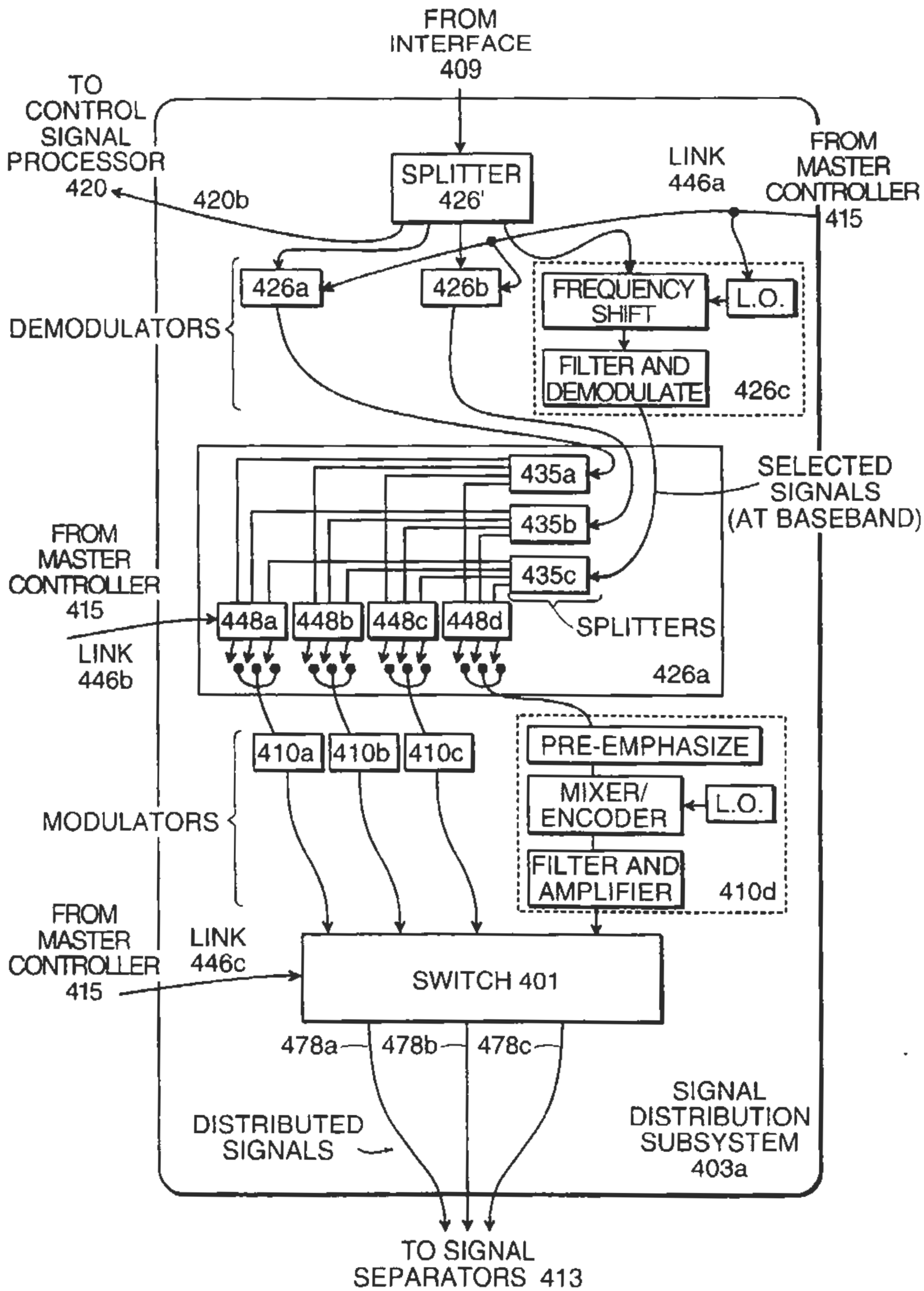

FROM
INTERFACE
409
TO
CONTROL
SIGNAL
PROCESSOR
420
420b
SPLITTER
426'
LINK
446a
FROM
MASTER
CONTROLLER
415
426a
426b
FREQUENCY
SHIFT
L.O.
DEMODULATORS
FILTER AND
DEMODULATE
426c
435a
SELECTED
SIGNALS
(AT BASEBAND)
435b
FROM
MASTER
CONTROLLER
415
435c
448a
448b
448c
448d
SPLITTERS
LINK
446b
426a
PRE-EMPHASIZE
410a
410b
410c
MIXER/
ENCODER
L.O.
MODULATORS
FILTER AND
AMPLIFIER
410d
FROM
MASTER
CONTROLLER
415
LINK
446c
SWITCH 401
478a
478b
478c
DISTRIBUTED
SIGNALS
SIGNAL
DISTRIBUTION
SUBSYSTEM
403a
TO SIGNAL
SEPARATORS 413

FIG. 5a

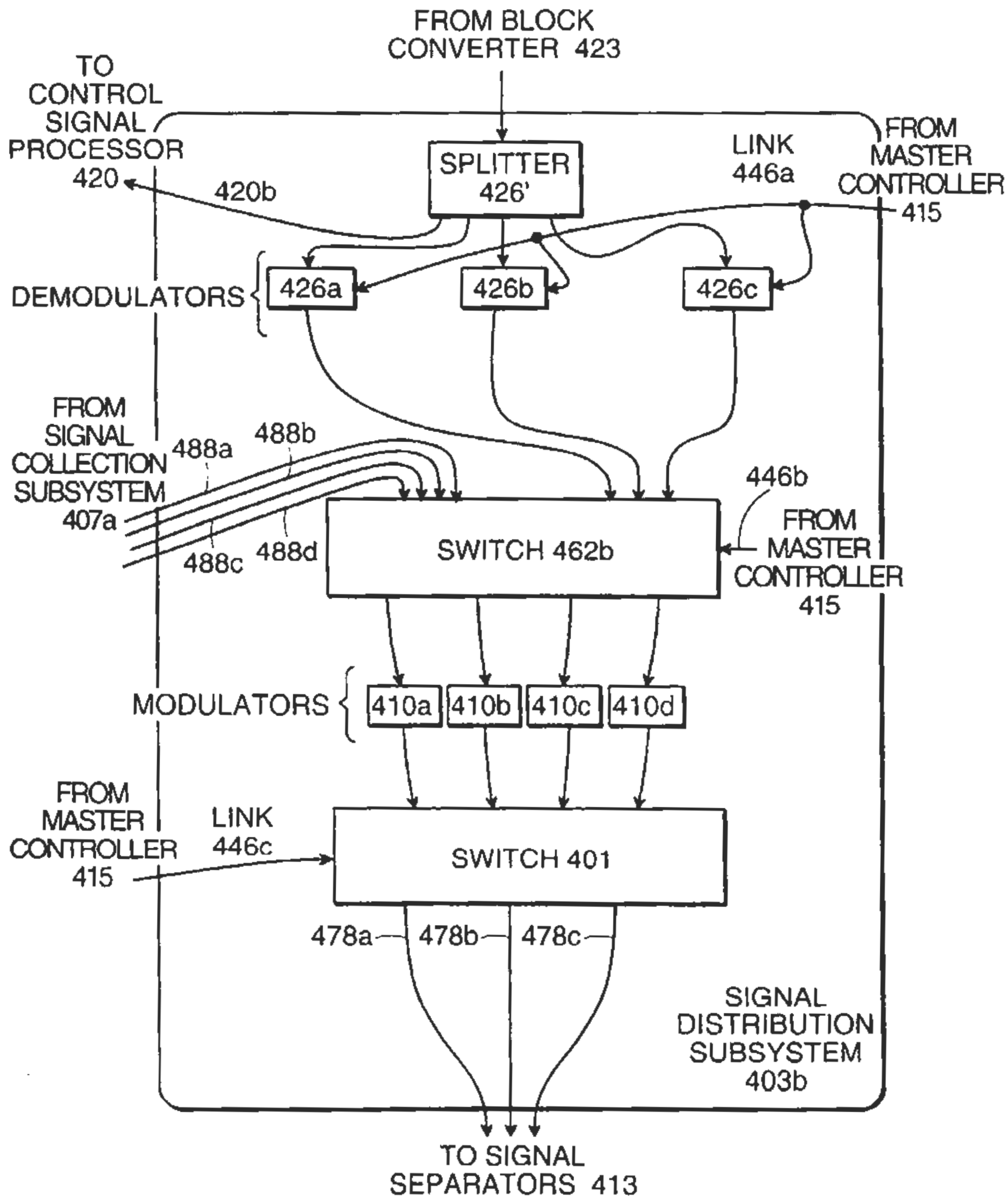

FROM BLOCK
CONVERTER 423
TO
CONTROL
SIGNAL
PROCESSOR
420
420b
SPLITTER
426'
LINK
446a
FROM
MASTER
CONTROLLER
415
DEMODULATORS
426a
426b
426c
FROM
SIGNAL
COLLECTION
SUBSYSTEM
407a
488a
488b
488c
488d
446b
SWITCH 462b
FROM
MASTER
CONTROLLER
415
MODULATORS
410a
410b
410c
410d
FROM
MASTER
CONTROLLER
415
LINK
446c
SWITCH 401
478a
478b
478c
SIGNAL
DISTRIBUTION
SUBSYSTEM
403b
TO SIGNAL
SEPARATORS 413

FIG. 5b

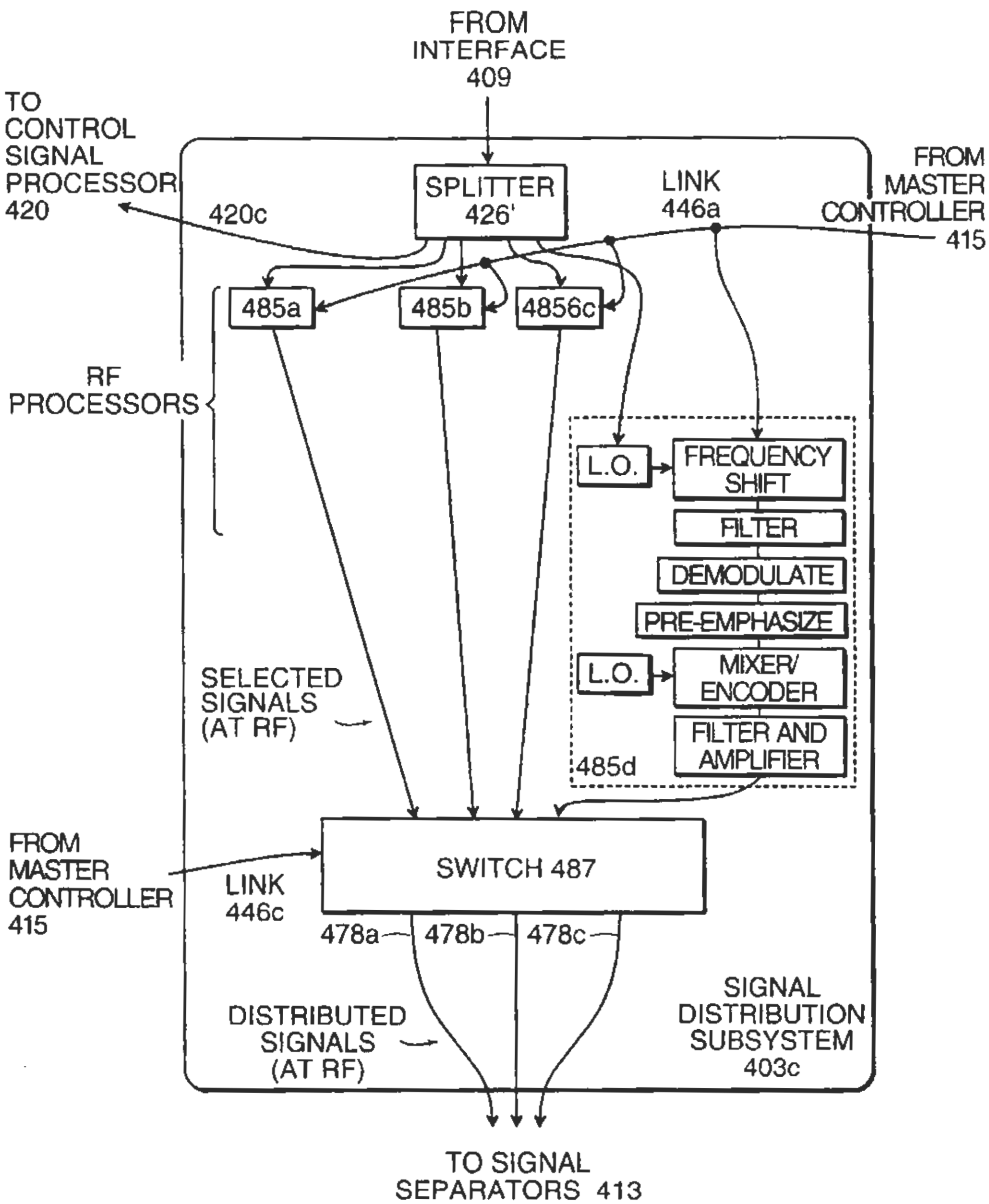

FROM
INTERFACE
409
TO
CONTROL
SIGNAL
PROCESSOR
420
420c
SPLITTER
426'
LINK
446a
FROM
MASTER
CONTROLLER
415
485a
485b
4856c
RF
PROCESSORS
L.O.
FREQUENCY
SHIFT
FILTER
DEMODULATE
PRE-EMPHASIZE
L.O.
MIXER/
ENCODER
FILTER AND
AMPLIFIER
485d
SELECTED
SIGNALS
(AT RF)
FROM
MASTER
CONTROLLER
415
LINK
446c
SWITCH 487
478a
478b
478c
DISTRIBUTED
SIGNALS
(AT RF)
SIGNAL
DISTRIBUTION
SUBSYSTEM
403c
TO SIGNAL
SEPARATORS 413

FIG. 5c

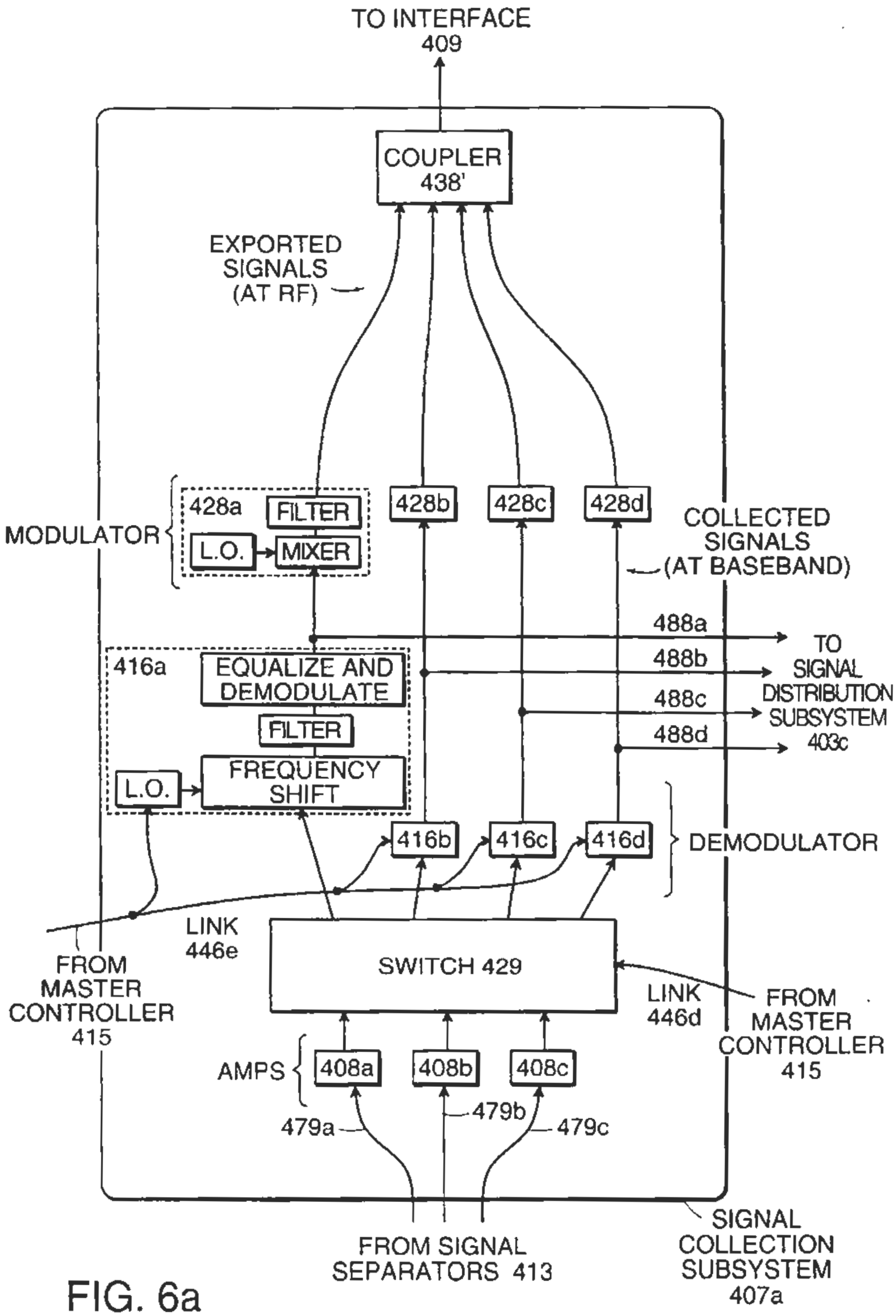

TO INTERFACE
409
COUPLER
438'
EXPORTED
SIGNALS
(AT RF)
MODULATOR
428a
FILTER
L.O.
MIXER
428b
428c
428d
COLLECTED
SIGNALS
(AT BASEBAND)
488a
488b
488c
488d
TO
SIGNAL
DISTRIBUTION
SUBSYSTEM
403c
416a
EQUALIZE AND
DEMODULATE
FILTER
L.O.
FREQUENCY
SHIFT
416b
416c
416d
DEMODULATOR
LINK
446e
SWITCH 429
FROM
MASTER
CONTROLLER
415
LINK
446d
FROM
MASTER
CONTROLLER
415
AMPS
408a
408b
408c
479a
479b
479c
FROM SIGNAL
SEPARATORS 413
SIGNAL
COLLECTION
SUBSYSTEM
407a

FIG. 6a

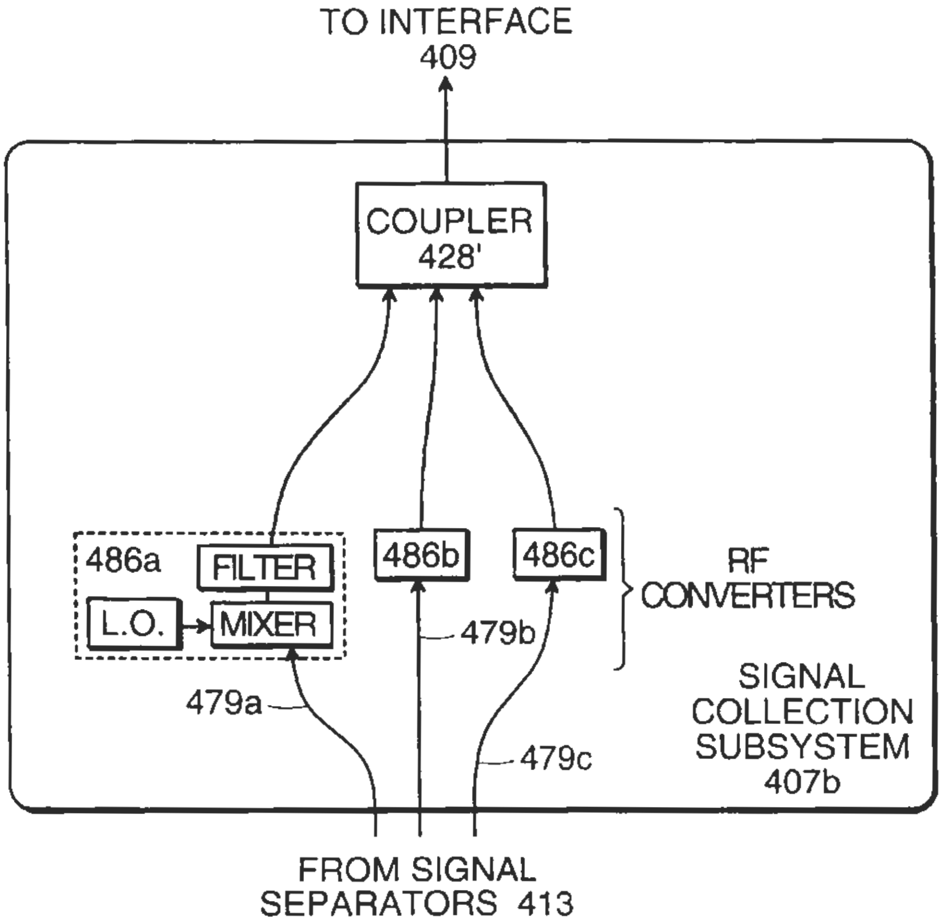

TO INTERFACE
409
COUPLER
428'
486a
FILTER
L.O.
MIXER
486b
486c
RF
CONVERTERS
479a
479b
479c
SIGNAL
COLLECTION
SUBSYSTEM
407b
FROM SIGNAL
SEPARATORS 413

FIG. 6b

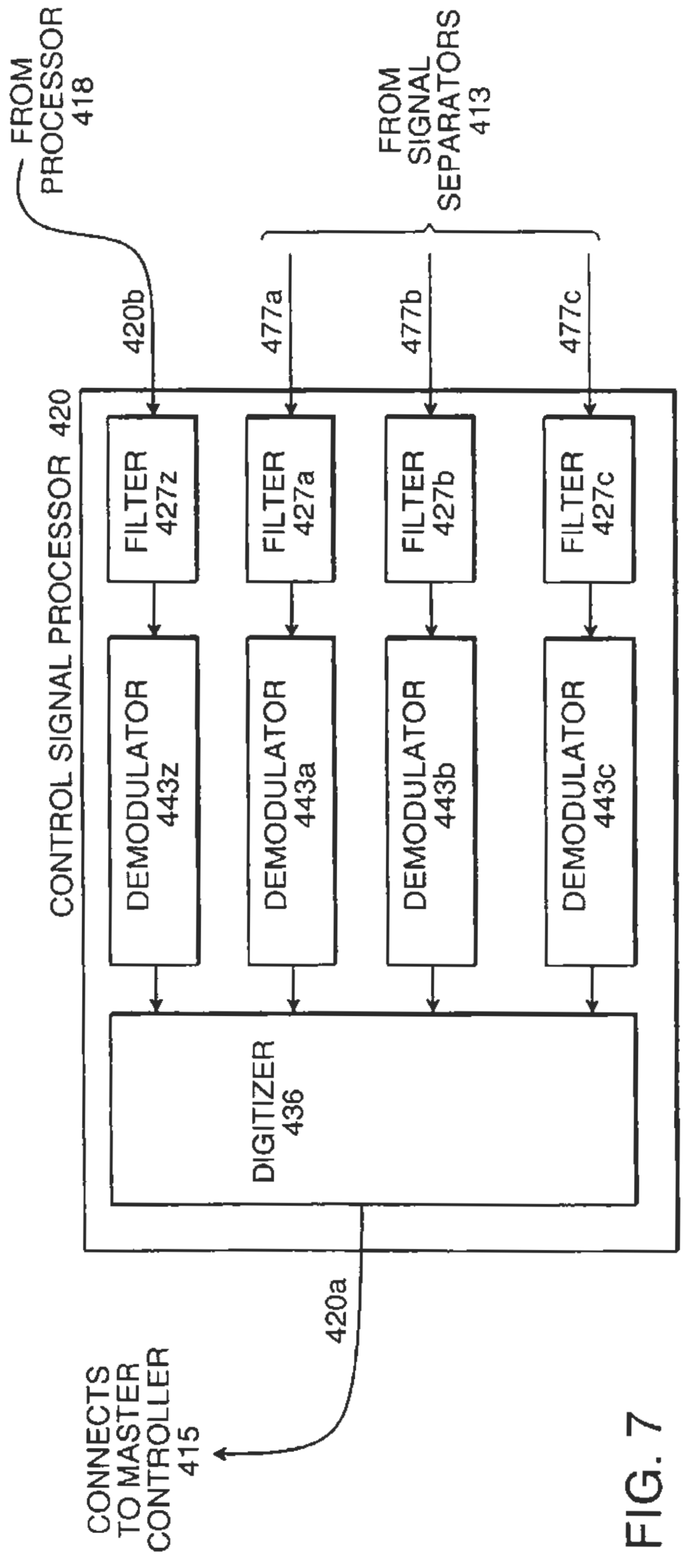

FROM PROCESSOR 418
FROM SIGNAL SEPARATORS 413
420b
477a
477b
477c
CONTROL SIGNAL PROCESSOR 420
FILTER 427z
FILTER 427a
FILTER 427b
FILTER 427c
DEMODULATOR 443z
DEMODULATOR 443a
DEMODULATOR 443b
DEMODULATOR 443c
DIGITIZER 436
420a
CONNECTS TO MASTER CONTROLLER 415

FIG. 7

FIG. 8

		FREQUENCY DURING TRANSMISSION OVER EXTENDED PAIRS (MHz)			FREQUENCY DURING TRANSMISSION OVER LOCAL NETWORKS (MHz)		
	ORIGIN/DEST	405a	405b	405c	411a	411b	411c
CONTROL A	493a/415	22.75-23.25			22.75-23.25		
B	493b/415		22.75-23.25			22.75-23.25	
C	493c/415			22.75-23.25			22.75-23.25
VIDEO U	402/492a	1-6(AM)			12-18(AM)		
V	402/492b 492c 498a	7-22(FM)	1-6(AM)	1-6(AM)	24-30(AM)	54-60(AM)	12-18(AM)
W	494b/402		24-54(FM)			6-12(AM)	
X	494c/402			24-54(FM)			6-12(AM)
DIGITAL Y	402/495c			6-18			18-40
Z	495c/402			54-100			1-6

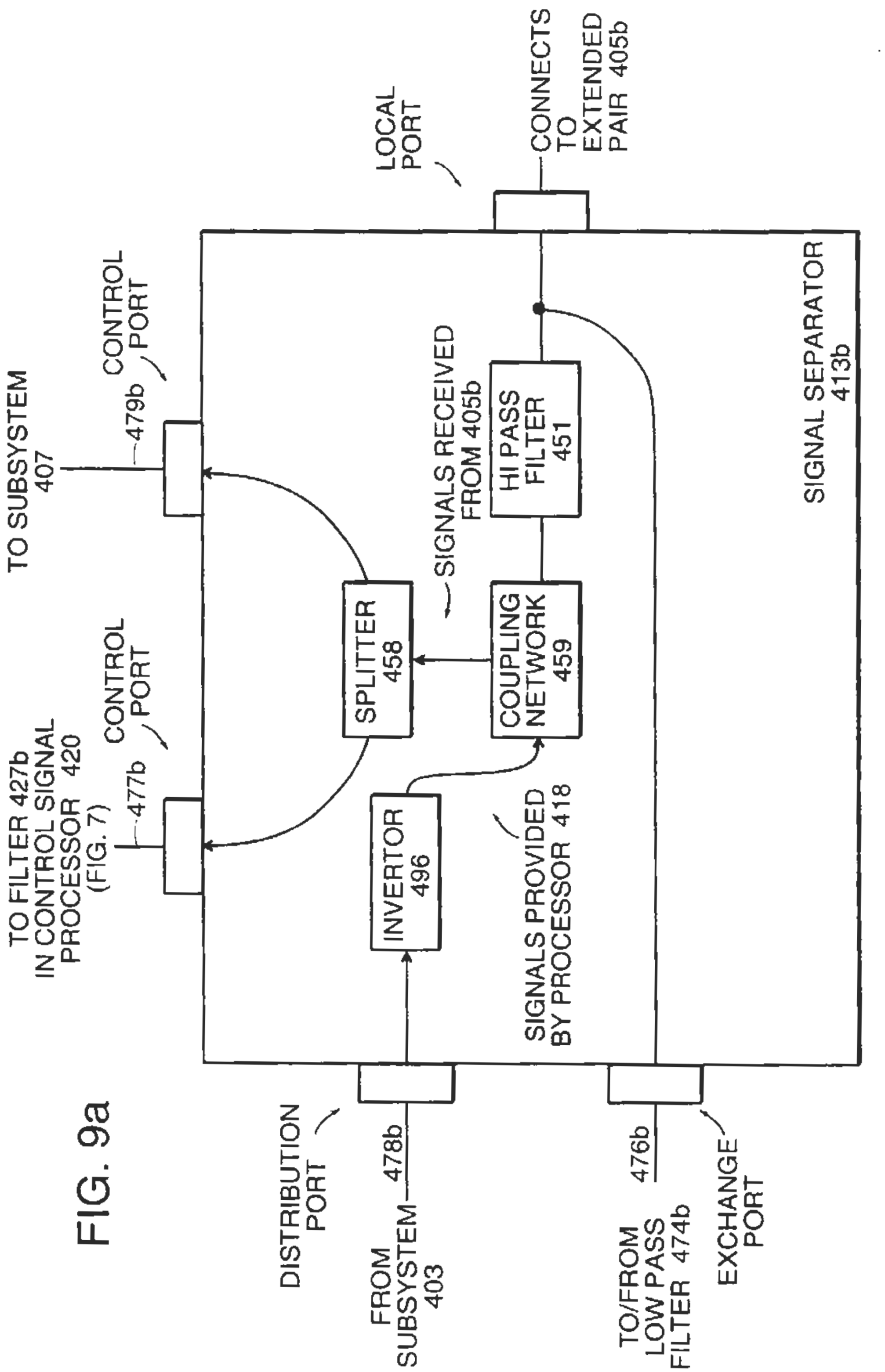

LOCAL PORT
CONNECTS TO EXTENDED PAIR 405b
TO SUBSYSTEM 407
CONTROL PORT
479b
SIGNALS RECEIVED FROM 405b
HI PASS FILTER 451
SIGNAL SEPARATOR 413b
SPLITTER 458
COUPLING NETWORK 459
TO FILTER 427b IN CONTROL SIGNAL PROCESSOR 420 (FIG. 7)
CONTROL PORT
477b
INVERTOR 496
SIGNALS PROVIDED BY PROCESSOR 418
DISTRIBUTION PORT
478b
FROM SUBSYSTEM 403
476b
TO/FROM LOW PASS FILTER 474b
EXCHANGE PORT

FIG. 9a

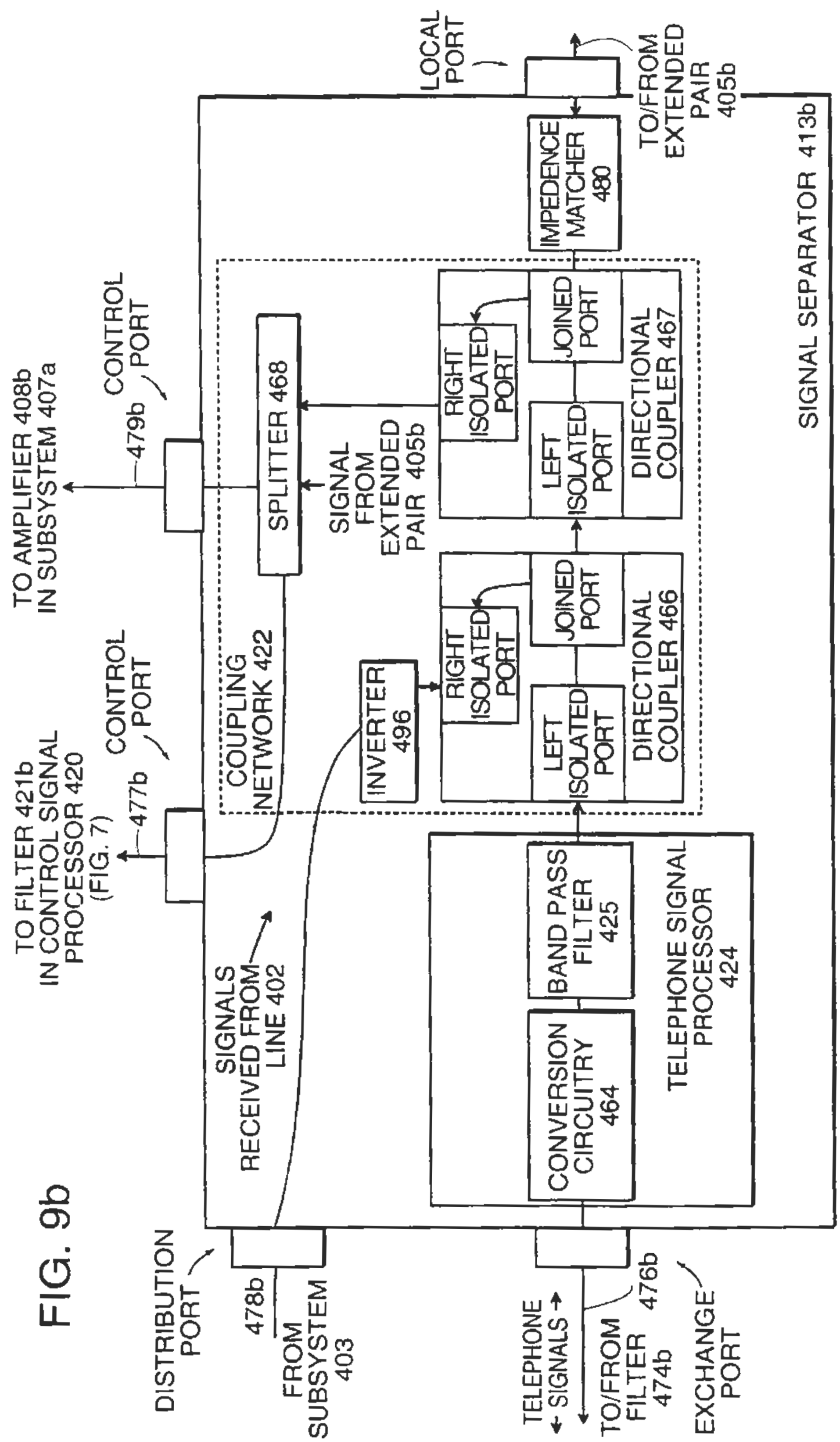

LOCAL PORT
TO/FROM EXTENDED PAIR 405b
IMPEDENCE MATCHER 480
SIGNAL SEPARATOR 413b
CONTROL PORT
479b
TO AMPLIFIER 408b IN SUBSYSTEM 407a
SPLITTER 468
SIGNAL FROM EXTENDED PAIR 405b
RIGHT ISOLATED PORT
JOINED PORT
LEFT ISOLATED PORT
DIRECTIONAL COUPLER 467
COUPLING NETWORK 422
INVERTER 496
RIGHT ISOLATED PORT
JOINED PORT
LEFT ISOLATED PORT
DIRECTIONAL COUPLER 466
CONTROL PORT
477b
TO FILTER 421b IN CONTROL SIGNAL PROCESSOR 420 (FIG. 7)
SIGNALS RECEIVED FROM LINE 402
BAND PASS FILTER 425
CONVERSION CIRCUITRY 464
TELEPHONE SIGNAL PROCESSOR 424
DISTRIBUTION PORT
478b
FROM SUBSYSTEM 403
TELEPHONE SIGNALS
TO/FROM FILTER 474b
476b
EXCHANGE PORT

FIG. 9b

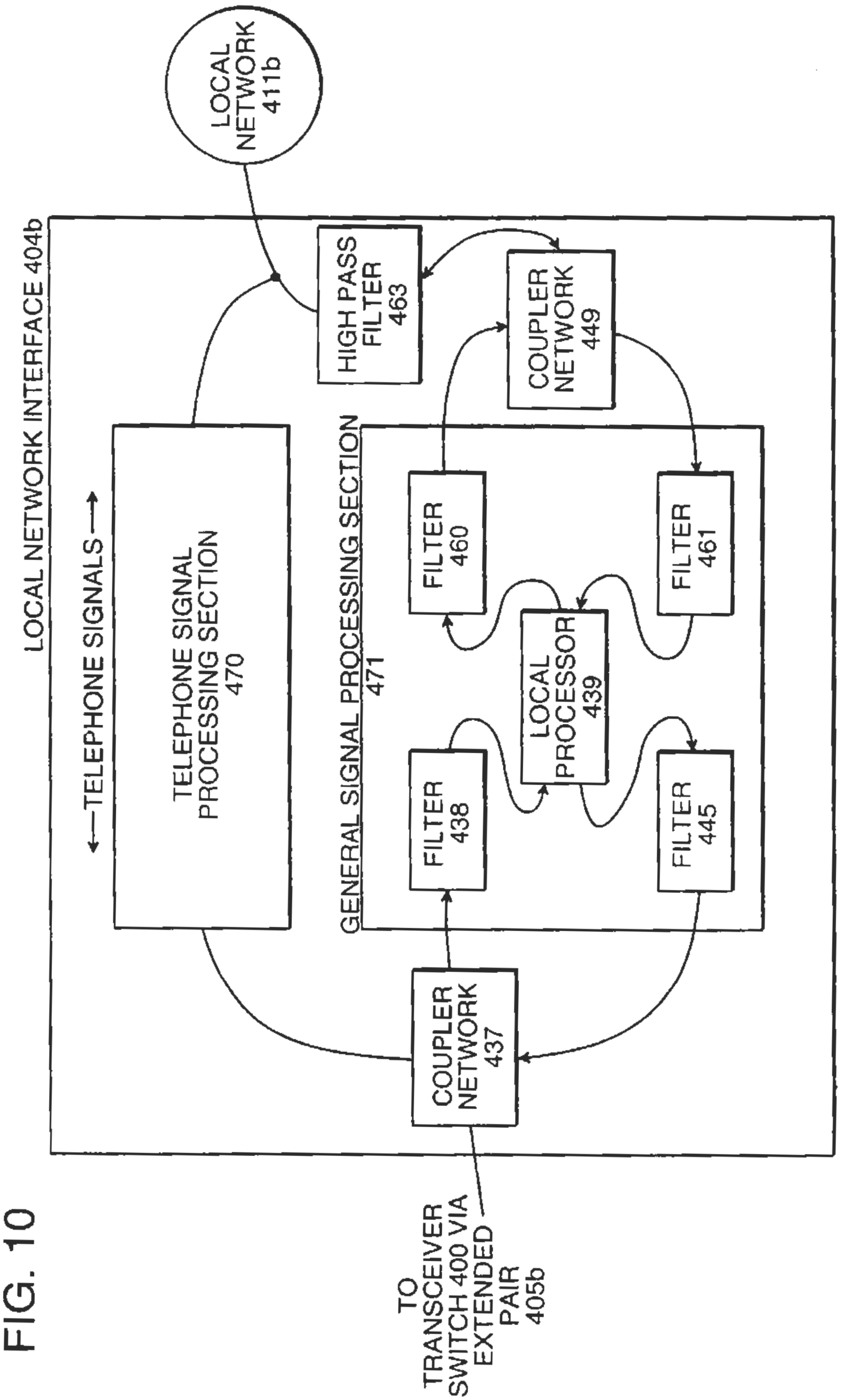

LOCAL NETWORK 411b
LOCAL NETWORK INTERFACE 404b
HIGH PASS FILTER 463
COUPLER NETWORK 449
TELEPHONE SIGNALS
TELEPHONE SIGNAL PROCESSING SECTION 470
GENERAL SIGNAL PROCESSING SECTION 471
FILTER 460
FILTER 461
LOCAL PROCESSOR 439
FILTER 438
FILTER 445
COUPLER NETWORK 437
TO TRANSCEIVER SWITCH 400 VIA EXTENDED PAIR 405b

FIG. 10

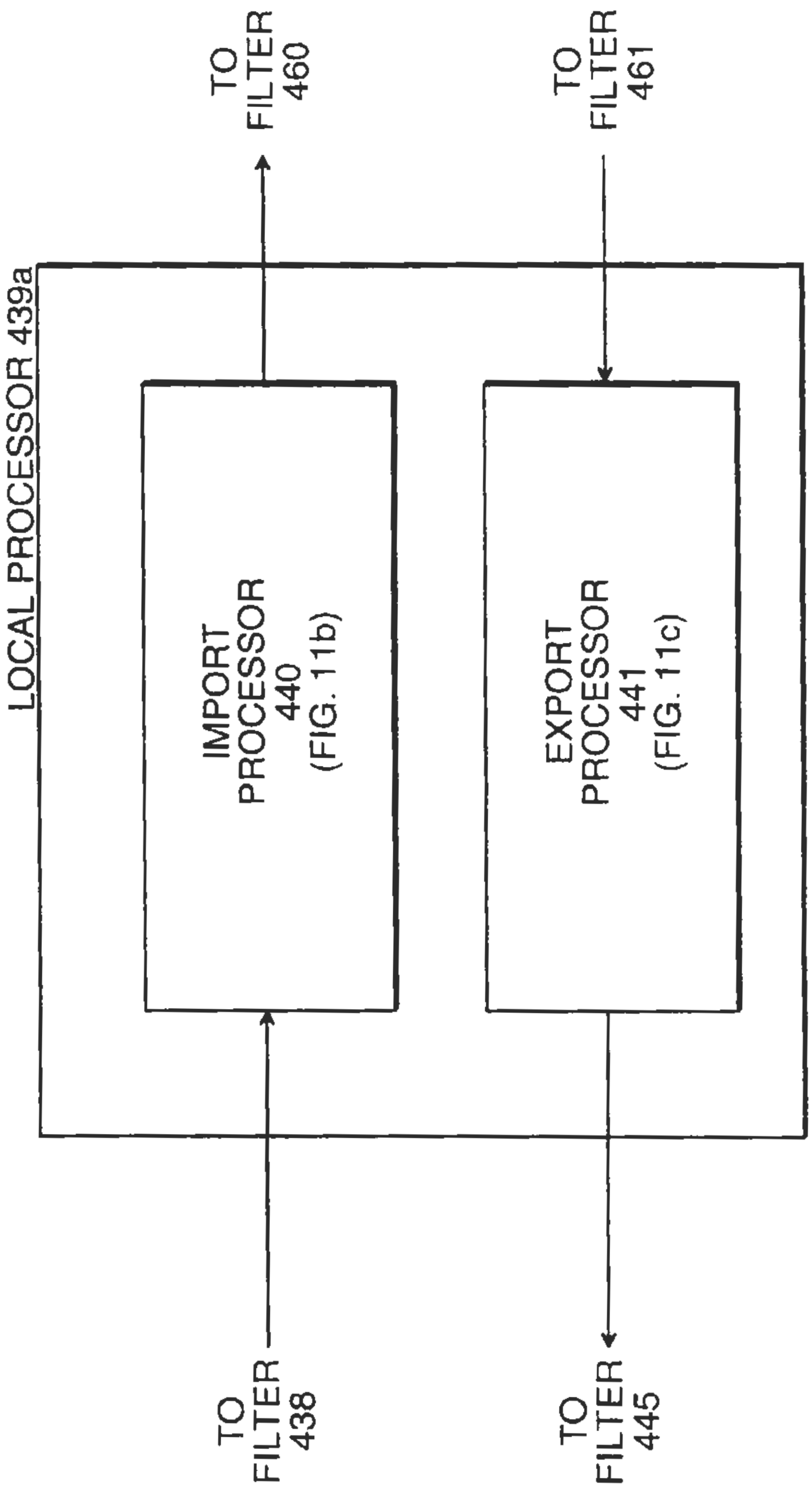

LOCAL PROCESSOR 439a
IMPORT PROCESSOR 440 (FIG. 11b)
EXPORT PROCESSOR 441 (FIG. 11c)
TO FILTER 460
TO FILTER 461
TO FILTER 438
TO FILTER 445

FIG. 11a

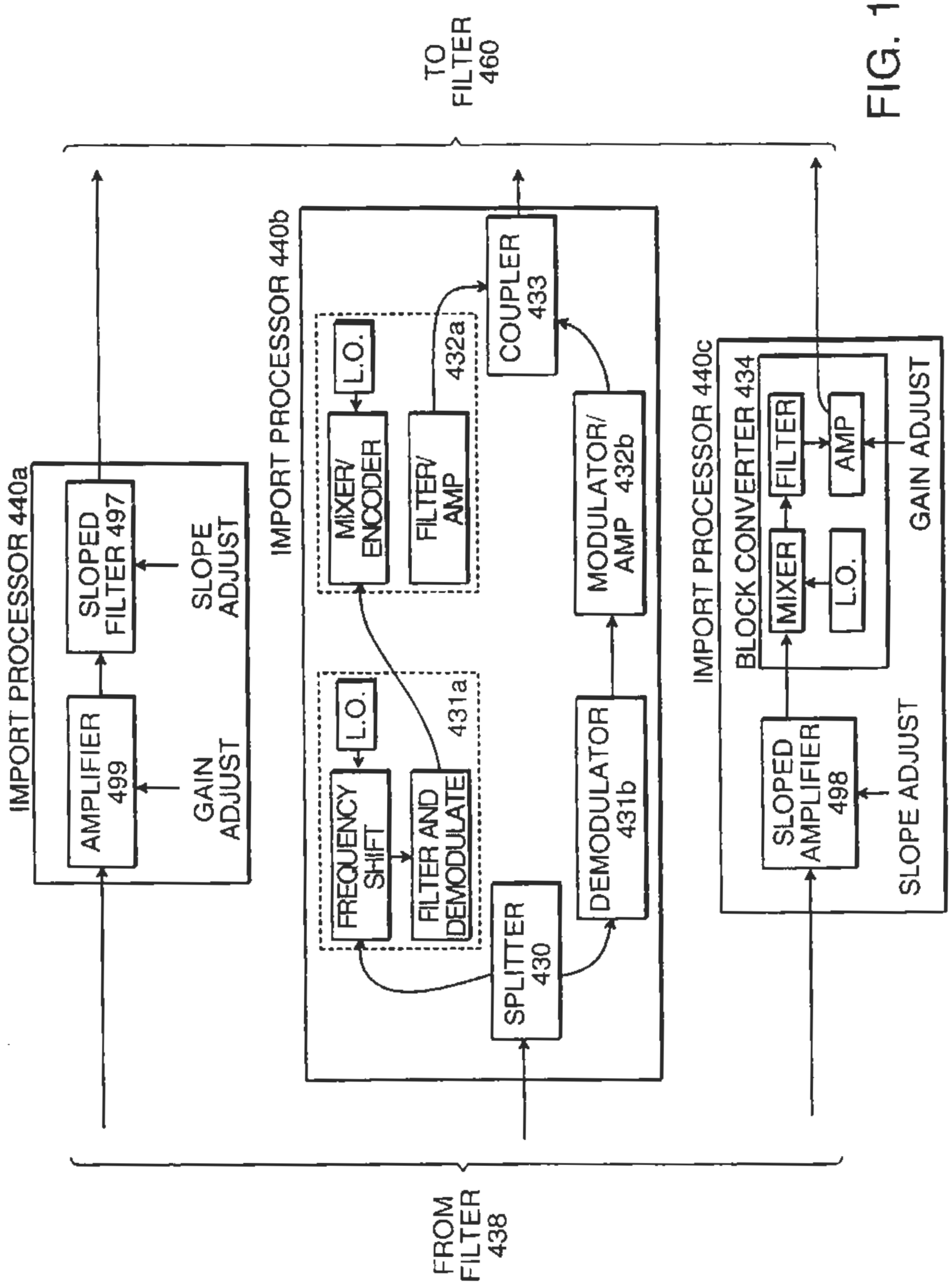

TO FILTER 460
IMPORT PROCESSOR 440a
AMPLIFIER 499
SLOPED FILTER 497
GAIN ADJUST
SLOPE ADJUST
IMPORT PROCESSOR 440b
SPLITTER 430
FREQUENCY SHIFT
L.O.
FILTER AND DEMODULATE
431a
MIXER/ ENCODER
L.O.
FILTER/ AMP
432a
COUPLER 433
DEMODULATOR 431b
MODULATOR/ AMP 432b
IMPORT PROCESSOR 440c
BLOCK CONVERTER 434
SLOPED AMPLIFIER 498
MIXER
L.O.
FILTER
AMP
SLOPE ADJUST
GAIN ADJUST
FROM FILTER 438

FIG. 11b

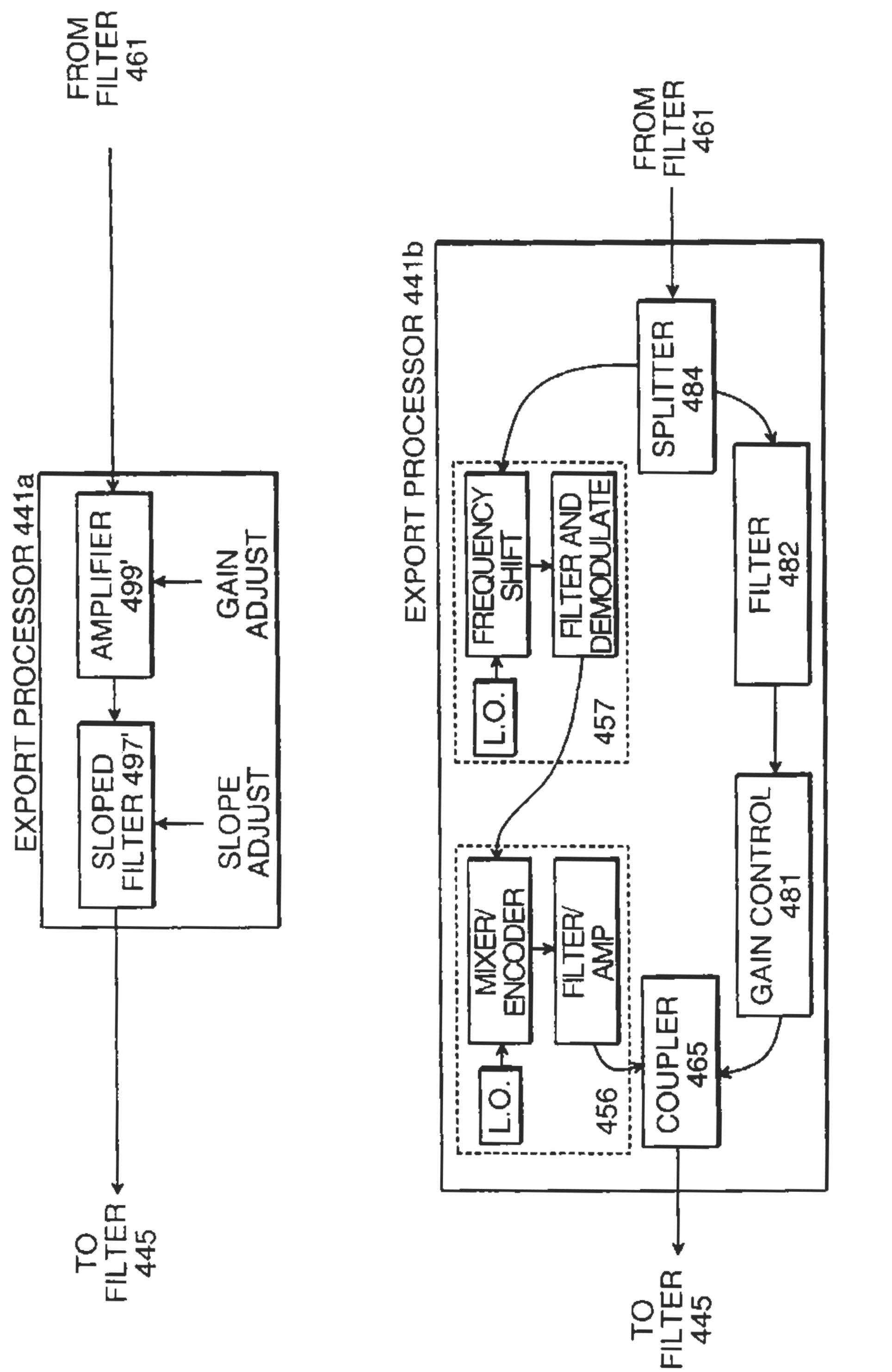

FROM FILTER 461
EXPORT PROCESSOR 441a
AMPLIFIER 499'
GAIN ADJUST
SLOPED FILTER 497'
SLOPE ADJUST
TO FILTER 445
FROM FILTER 461
EXPORT PROCESSOR 441b
SPLITTER 484
FREQUENCY SHIFT
FILTER AND DEMODULATE
L.O.
457
FILTER 482
MIXER/ ENCODER
FILTER/ AMP
L.O.
456
COUPLER 465
GAIN CONTROL 481
TO FILTER 445

FIG. 11c

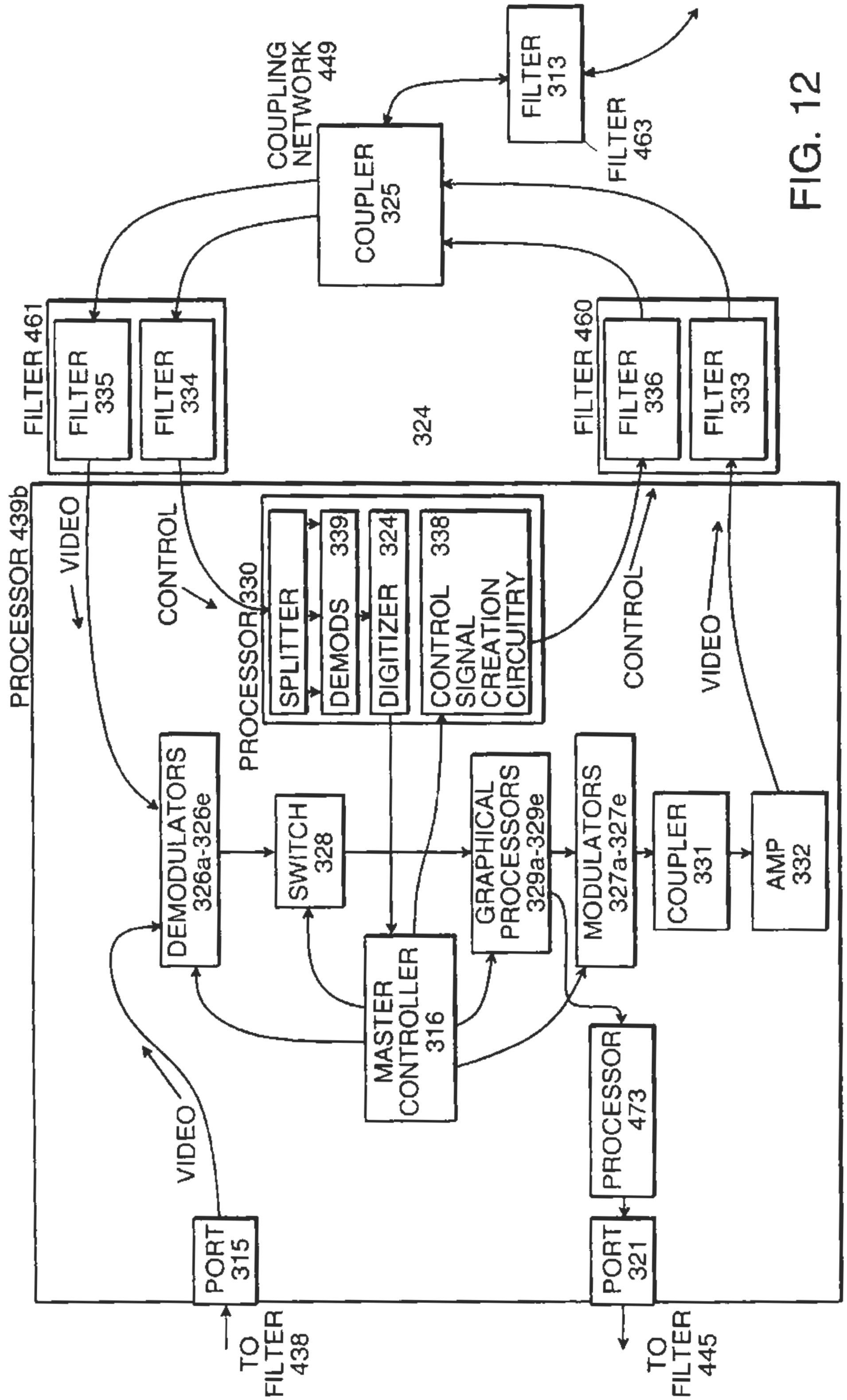

COUPLING NETWORK 449
FILTER 313
FILTER 463
COUPLER 325
FILTER 461
FILTER 335
FILTER 334
324
FILTER 460
FILTER 336
FILTER 333
PROCESSOR 439b
VIDEO
CONTROL
PROCESSOR 330
SPLITTER
DEMODS 339
DIGITIZER 324
CONTROL SIGNAL CREATION CIRCUITRY 338
CONTROL
VIDEO
DEMODULATORS 326a-326e
SWITCH 328
GRAPHICAL PROCESSORS 329a-329e
MODULATORS 327a-327e
COUPLER 331
AMP 332
MASTER CONTROLLER 316
PROCESSOR 473
VIDEO
PORT 315
PORT 321
TO FILTER 438
TO FILTER 445

FIG. 12

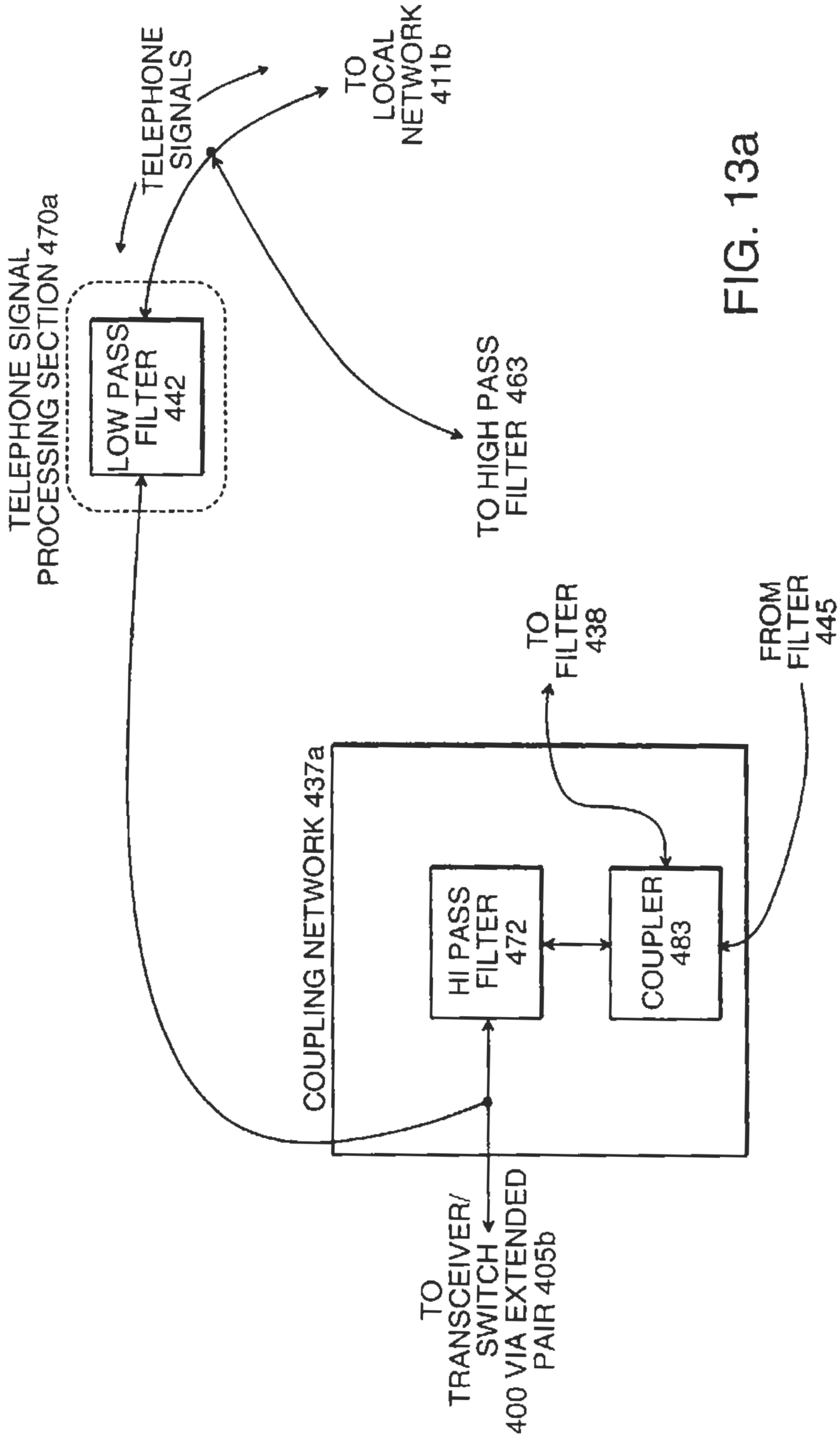

TELEPHONE SIGNALS
TO LOCAL NETWORK 411b
TELEPHONE SIGNAL PROCESSING SECTION 470a
LOW PASS FILTER 442
TO HIGH PASS FILTER 463
TO FILTER 438
FROM FILTER 445
COUPLING NETWORK 437a
HI PASS FILTER 472
COUPLER 483
TO TRANSCEIVER/ SWITCH 400 VIA EXTENDED PAIR 405b

FIG. 13a

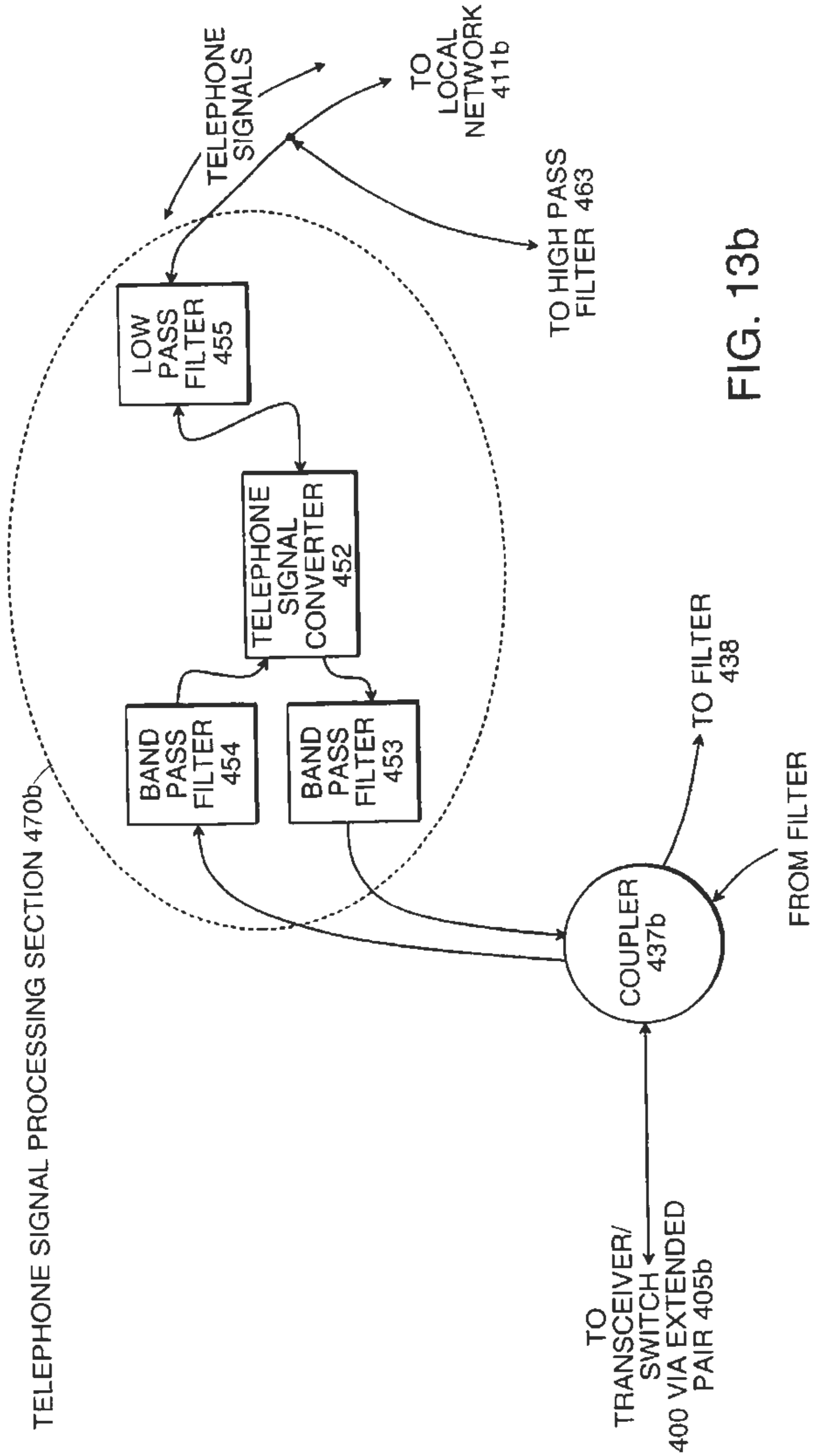
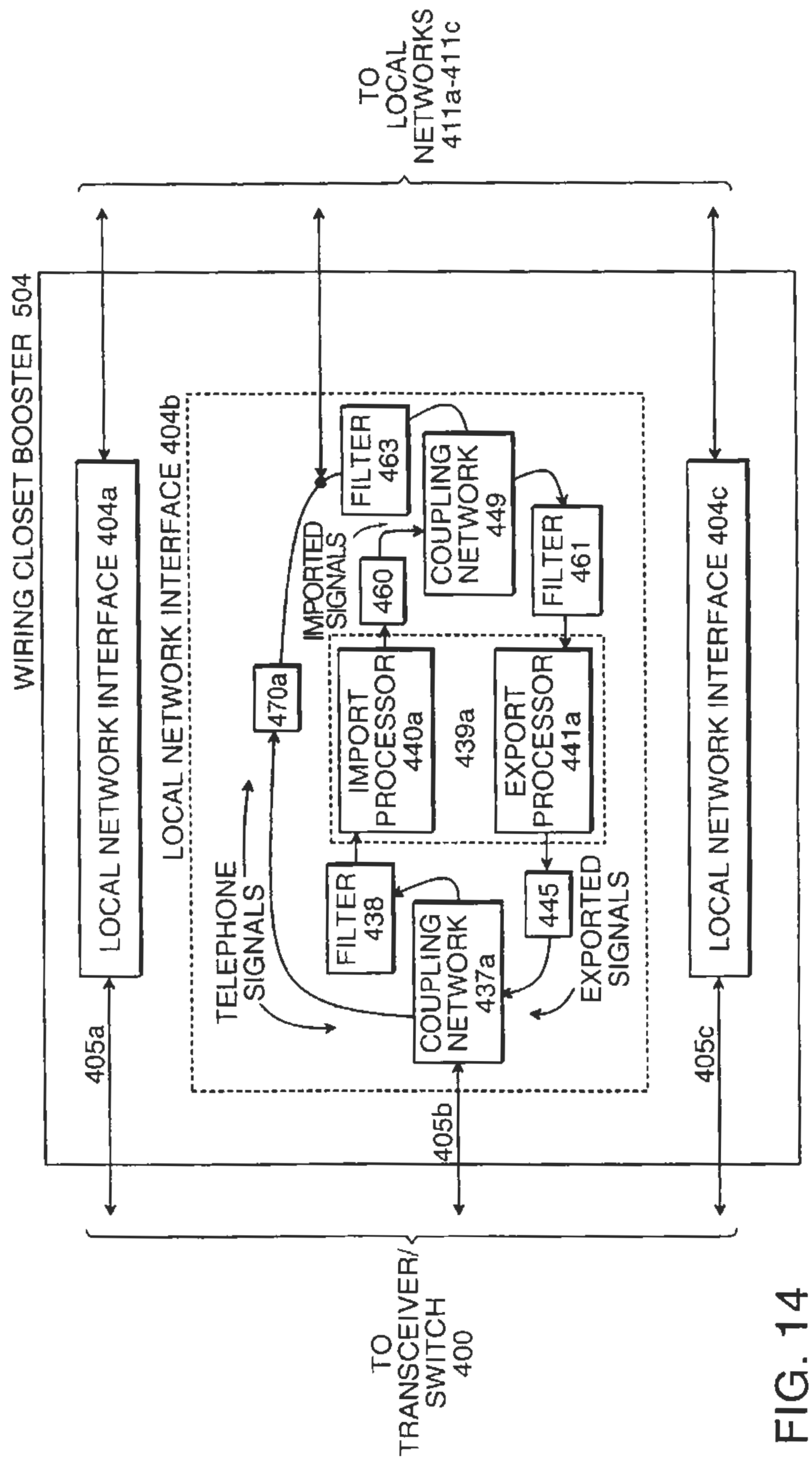

TELEPHONE SIGNALS
TO LOCAL NETWORK 411b
TO HIGH PASS FILTER 463
LOW PASS FILTER 455
TELEPHONE SIGNAL CONVERTER 452
BAND PASS FILTER 454
BAND PASS FILTER 453
TO FILTER 438
FROM FILTER 445
COUPLER 437b
TELEPHONE SIGNAL PROCESSING SECTION 470b
TO TRANSCEIVER/ SWITCH 400 VIA EXTENDED PAIR 405b

FIG. 13b



TO LOCAL NETWORKS 411a-411c
WIRING CLOSET BOOSTER 504
LOCAL NETWORK INTERFACE 404a
LOCAL NETWORK INTERFACE 404b
LOCAL NETWORK INTERFACE 404c
FILTER 463
COUPLING NETWORK 449
FILTER 461
IMPORTED SIGNALS
460
470a
IMPORT PROCESSOR 440a
439a
EXPORT PROCESSOR 441a
TELEPHONE SIGNALS
FILTER 438
445
EXPORTED SIGNALS
COUPLING NETWORK 437a
405a
405b
405c
TO TRANSCEIVER/ SWITCH 400

FIG. 14

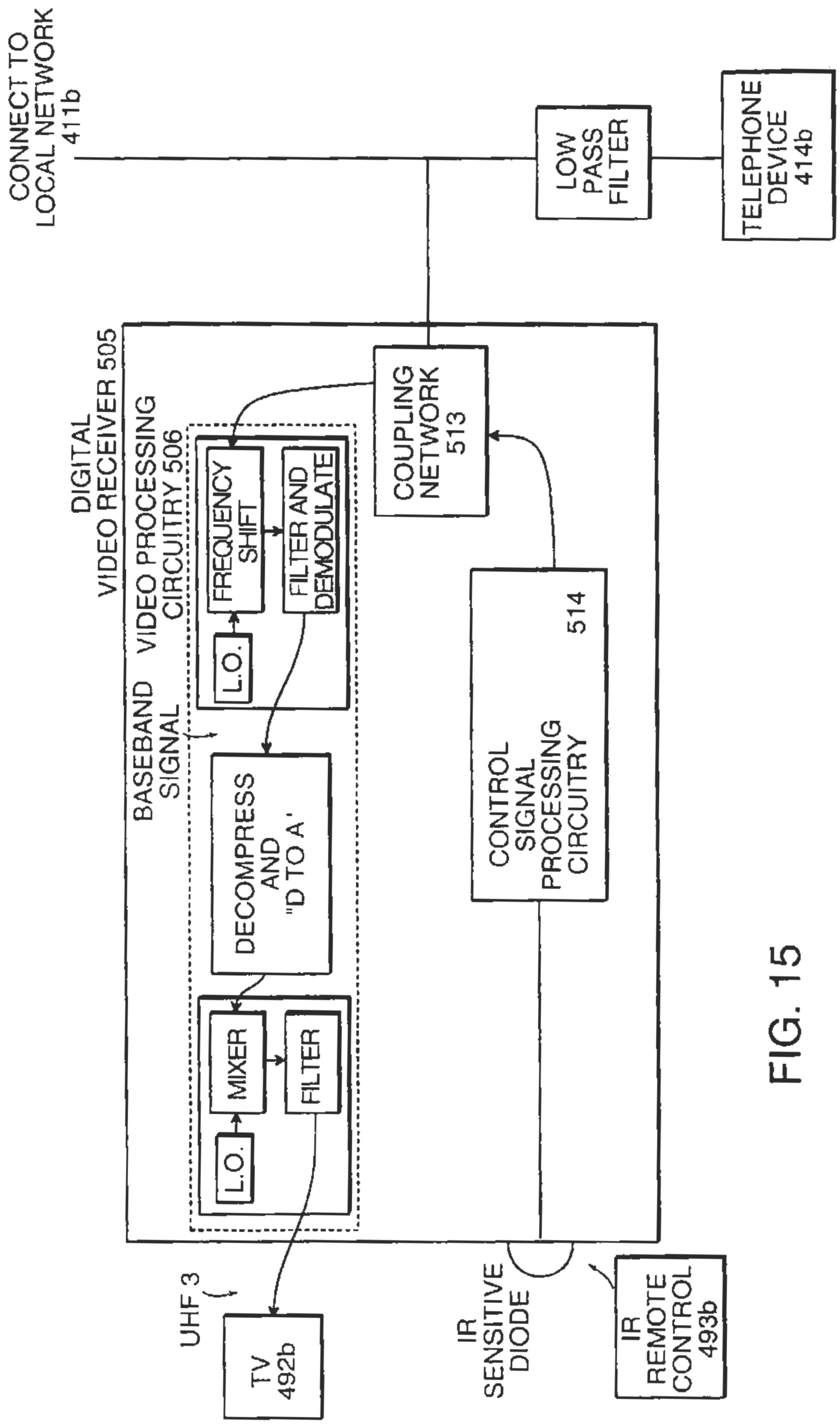

CONNECT TO
LOCAL NETWORK
411b
LOW
PASS
FILTER
TELEPHONE
DEVICE
414b
DIGITAL
VIDEO RECEIVER 505
VIDEO PROCESSING
CIRCUITRY 506
COUPLING
NETWORK
513
FREQUENCY
SHIFT
FILTER AND
DEMODULATE
L.O.
BASEBAND
SIGNAL
DECOMPRESS
AND
"D TO A"
CONTROL
SIGNAL
PROCESSING
CIRCUITRY
514
MIXER
FILTER
L.O.
UHF 3
TV
492b
IR
SENSITIVE
DIODE
IR
REMOTE
CONTROL
493b

FIG. 15

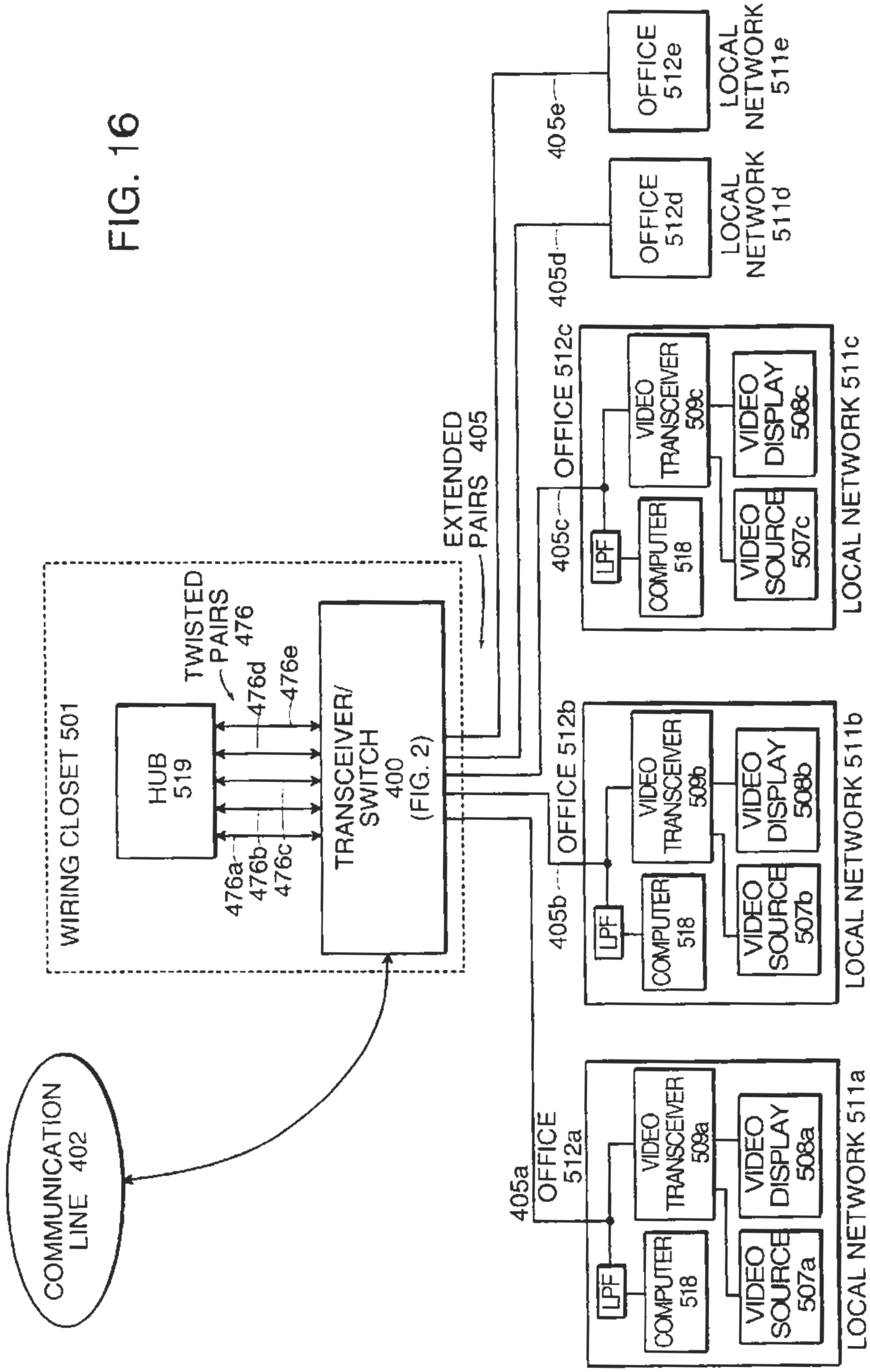

WIRING CLOSET 501
HUB 519
TWISTED PAIRS 476
476a
476b
476c
476d
476e
TRANSCEIVER/ SWITCH 400 (FIG. 2)
COMMUNICATION LINE 402
EXTENDED PAIRS 405
405a
405b
405c
405d
405e
OFFICE 512a
OFFICE 512b
OFFICE 512c
OFFICE 512d
OFFICE 512e
LPF
COMPUTER 518
VIDEO TRANSCEIVER 509a
VIDEO TRANSCEIVER 509b
VIDEO TRANSCEIVER 509c
VIDEO DISPLAY 508a
VIDEO DISPLAY 508b
VIDEO DISPLAY 508c
VIDEO SOURCE 507a
VIDEO SOURCE 507b
VIDEO SOURCE 507c
LOCAL NETWORK 511a
LOCAL NETWORK 511b
LOCAL NETWORK 511c
LOCAL NETWORK 511d
LOCAL NETWORK 511e

FIG. 16

DISTRIBUTED SPLITTER FOR DATA TRANSMISSION OVER TWISTED WIRE PAIRS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Ser. No. 09/191,168, filed Nov. 13, 1998, which is a continuation of U.S. Ser. No. 08/814,837, filed on Mar. 11, 1997, which issued as U.S. Pat. No. 5,844,596 on Dec. 1, 1998, which is a continuation of U.S. Ser. No. 08/673,577, filed on Jul. 1, 1996, which is a continuation of U.S. Ser. No. 08/545,937, filed on Oct. 20, 1995, which is a continuation of 08/372,561, filed on Jan. 13, 1995, which is a continuation of U.S. Ser. No. 08/245,759, filed on May 18, 1994, which is a continuation of U.S. Ser. No. 08/115,930, filed on Aug. 31, 1993, which is a continuation of U.S. Ser. No. 07/802,738, filed on Dec. 5, 1991, which is a continuation of U.S. Ser. No. 07/688,864, filed on Apr. 19, 1991, which is a continuation-in-part of U.S. Ser. No. 07/379,751, filed on Jul. 14, 1989, which issued as U.S. Pat. No. 5,010,399 on Apr. 23, 1991.

INTRODUCTION

The present invention relates to a system for simultaneous two-way communication of video signals and other signals between multiple networks of telephone wiring whose twisted pairs converge together into a single bundle, wiring block, or other common point of access, and a high capacity communication line located at that point of access. Each network includes a set of interconnected, active telephone wires (i.e., a group of wires that create a conductive path for telephonic signals) internal to a house, an apartment unit, or a room in a commercial building. (Such wiring internal to houses, apartment units, or rooms in commercial buildings shall be referred to herein as "local networks.") In the case of houses, the point of common access can be a telephone pole. In the case of apartment buildings, the point of access can be the "wiring closets" found in those buildings. In the case of commercial buildings, the point of access can be the electronic PBX, or "private branch exchange" common to those types of buildings. The high capacity line can be a coaxial cable or an optical fiber. In addition to communication between each network and the high capacity line, communication from one network to another is also provided.

This invention is partly an outgrowth of technology presented in the parent application, and two other continuations-in-part thereof, respectively entitled "RF Broadcast System Utilizing Internal Telephone Lines" (hereinafter, the "first CIP application") and "Cable TV Distribution and Communication System Utilizing Internal Telephone Wiring" (hereinafter, the "second CIP application"). The first and second CIP applications were filed on the same day as this application. The parent application and the first and second CIP applications are incorporated herein by reference.

The communication systems disclosed in the parent and first and second CIP applications are designed to simultaneously transmit telephone signals and non-telephonic signals (such as cable television signals, other video signals, audio signals, data signals, and control signals) across the active telephone wiring internal to (i.e., locally within) residences and other structures. The present invention adds to these techniques, providing distribution of all of these signals to a local network of active telephone wiring (i.e. the wiring internal to a house, apartment unit, or a room in a commercial building) from a distribution device that connects to the trunk line of a public or private telephone network. That device is located where the telephone lines for multiple local networks converge to meet the public network trunk (or PBX, in the case of office buildings), enabling the distribution device to perform communication functions for many local networks at once, including communication between one local network and another. The distribution system works just as well when the point of convergence is the center of a computer communications network with a "star" topology, and the wires are the twisted pair wires connecting each individual computer to this center.

BACKGROUND OF THE INVENTION

The current method of providing cable TV signals to a house requires that a cable branch (typically a coaxial cable) connect from the main cable trunk to each subscriber. In addition, at the end of the subscriber branch, an additional segment of the coaxial cable must be installed for every extra TV "hookup" within the residence.

The challenge of providing cable TV to an apartment building is even more formidable. If coaxial cabling is not included at the time of construction, a coaxial cable leading through the entire building must be installed, and a branch must connect between each of the individual apartment units to a point on this cable. This is obviously an expensive procedure, even if easily accessible cabling conduits exist. Furthermore, each branch provides service at only one location within the unit it connects. Extra branches must be installed to provide cable TV service at other locations in the unit.

Providing a group of TV signals to various rooms in an office building currently requires a similar amount of coaxial cable installation. The demand for economical video distribution within office buildings is increasing, moreover, because of the increased popularity of video teleconferencing.

The method of distributing cable TV signals commonly used in the U.S. can be called a "one-way branched" system because signals transmitted at the head-end (i.e., at the root or entrance point to the network) spread across to each of the various subscribers by continually splitting into multiple downstream branches. Due to an increase in the popularity of video programming, however, demand for a new system has emerged. Under the new system, sometimes called "video on demand," a subscriber can request a specific program from a library of programs stored at a central location on, for example, video tapes. The signal from this program is subsequently sent to the subscriber from the "head end" of the system. No other viewers can receive the same signal unless they make a similar request.

One method for providing video on demand is to install a high-capacity fiber optic transmission line from the library through a series of residential or commercial neighborhoods. At each neighborhood, all signals targeted for the local residences or businesses (hereinafter, the term "residence" is used to mean both types of buildings unless otherwise stated) are encoded (i.e. scrambled) and then "handed off" at different channels onto the coaxial cable branch that feeds those residences. Thus, each neighborhood has its own individual headend at the point of handoff.

To prevent all residences from receiving each of the signals handed off to their neighborhood, a control signal is sent over the fiber optic transmission line that includes the "address" of a converter box in the house of the subscriber who requests a particular signal. This control signal provides

descrambling instructions that, because of the addressing, only the targeted converter box will recognize. Under this system, each subscriber receives all signals targeted for his or her neighborhood, but only the program (i.e., the specific video signal) actually requested by a subscriber becomes available to him or her in unscrambled form.

The concept of "video on demand" can be considered to be part of a broader communication concept. The broader concept is the widening of communication paths to the ordinary subscribers on the switched public communication network. This would enable subscribers to communicate video signals and other relatively wide bandwidth signals in the same way that they currently communicate voice signals.

The transmission medium that is best suited to provide wider communication paths is fiber optic cables. Indeed, many of the public telephone companies have converted most of their main communication trunks to fiber optics, and have upgraded their switching equipment to handle these signals and their attendant increase in data rates.

To bring the wider capacity to an individual site, however, requires one to install a new fiber optic branch from the main fiber optic trunk to each local network (i.e. a house, apartment unit, or a room in an office building), and to switch signals from the trunk onto the branches. Furthermore, conversion from light to electrical signals must take place at the point where the branch reaches the targeted residence. (Conversion is necessary because the communication devices currently found in typical residences and offices respond to electrical signals.) Finally, the electrical signals must be distributed through the house.

SUMMARY OF THE INVENTION

The invention described in the second CIP application eliminates the need for installation of multiple coaxial cable branches within a residence. Once a feed from the main cable trunk is brought to a house or apartment unit, the technology described in that application can transmit signals from that feed onto the internal active telephone wiring of the residence, using those wires to carry the signals to the individual televisions. Thus, only the coaxial cable which leads from the main cable trunk to the residence is necessary.

One general concept that this invention provides is the use of active telephone wiring (i.e., wiring that is also used for its normal purpose to carry telephone signals) as the transmission line leading from a main cable trunk (which is coaxial cable or fiber optics) to the individual subscribers. This significantly reduces the complexity and expense normally associated with cable TV wiring, above the reduction described in the second CIP application. A major advantage of this wiring over coaxial cable is that nearly every residence (such as an individual house or an apartment unit in an apartment building) has one or more phone lines, each including at least one twisted pair (e.g., the red-green pair; typically, a second twisted pair of black-yellow wires is also provided) leading to it from the telephone company trunk line. A second advantage is that signals applied to the telephone line are available at every telephone jack, rather than at a single coaxial outlet.

Thus, a general aspect of this invention is a system that provides video signal communication between a source of the video signal and a plurality of units that include destinations of the video signal and that includes an interface coupled to the source and to telephone lines, each of which serves at least one of the units and carries voice signals to and from one or more telephones coupled to the telephone line at said unit. The interface receives the video signal from

the source, and transmits the received video signal onto at least one of the telephone lines in a selected frequency range that is different from frequencies at which the voice signals are carried on that telephone line. This causes the video signal to be coupled to a receiver which is connected to the telephone line at the unit served by that line and is adapted to recover the video signal from the telephone line and apply it to one or more of the destinations at the unit.

Preferred embodiments include the following features.

The source is a cable (e.g., electrical or fibre optic) that is linked to the interface and that carries a plurality of video signals. The destinations are, e.g., televisions. The units can be residences (such as individual houses or apartments in an apartment building) or offices in an office building. Hereinafter, the term "residence" will be used for all such units.

The interface is adapted to select one or more of the video signals in response to control information from a user or users of televisions at any residence and transmit the selected video signal or signals onto the telephone line that serves that residence for recovery and application to one or more televisions in the residence. If multiple video signals are selected for a given residence, the interface transmit the video signals onto the telephone line that serves that residence at different frequencies within the selected frequency range. This prevents the selected video signals from interfering with each other.

The interface can select the same video signal for multiple residences and transmit the video signal onto the plurality of telephone lines that serve those residences. Further, the same video signal can be sent over the telephone lines at the same or different frequencies.

At least one of the residences includes an internal telephone link to which its receiver and at least one telephone is connected. The internal telephone link is connected to the telephone line that serves that residence, either directly or via a local interface. The local interface amplifies video signals received over the telephone line and couples them onto the internal telephone link. This helps compensate for attenuation that typically occurs during transmission to the local interface, thereby increasing the quality of the video signals recovered by the receiver.

At least one of the residences includes a source (e.g., a video camera) that applies a second video signal that applies said second video signal onto the internal telephone link in a second selected frequency range that is different from both the frequency range selected by the interface and the frequencies at which the voice signals are carried on the telephone link. The local interface amplifies the second video signal and couples it onto the telephone line that serves the residence to cause the second video signal to be coupled to the interface. The interface, in turn, transmits the second video signal to the source.

The interface is coupled between the telephone lines and corresponding public telephone lines (which carry voice signals at voiceband frequencies) that serve the residences. In one embodiment, the interface couples the voice signals between each public telephone line and each telephone line at voiceband frequencies, and the selected frequency range exceeds the voiceband frequencies.

In another embodiment, the interface converts the voice signals on the public telephone lines to a frequency range above voiceband frequencies before coupling the voice signals onto the telephone lines for transmission to the residences. In this case, at least a portion of the selected frequency range for the video signals includes voiceband

frequencies. The local interfaces at the residences reconvert the voice signals to voiceband frequencies and change the frequency of the video signals to a frequency band above voiceband frequencies before coupling the voice signals and the video signals onto the internal telephone link.

A possible drawback of using active telephone wiring to transmit video signals (e.g., cable TV signals) to the residence according to this aspect of the invention is that the number of signals that can be effectively transmitted may be more limited. This, however, can be solved because only a very limited number of signals are typically useful at a single time. One recommended solution is to locate the channel selection device at the point of connection to the main telephone trunk (also called the "point of convergence" of telephone lines from multiple residences) and send only the selected video signals to each residence via the telephone line.

This arrangement can actually achieve extra economies if telephone lines from several subscribers converge at one point, as they do in apartment buildings and sometimes on telephone poles or pedestals. One economy that can result is that the channel selection electronics for several subscribers can be embodied in a single device, thereby reducing hardware cost. The second economy is that scrambling of the signals is not necessary. Signals not paid for by a subscriber will simply not be handed off onto the telephone lines leading to the residence of that subscriber.

Ordinarily, piracy would be a problem because it is easier to "tap" an RF signal from a twisted pair, which is unshielded, than from a coaxial cable. Furthermore, a "tap" onto a twisted pair is less obvious than a tap onto a cable. Because the signals are "handed off" from a point of convergence, however, only specifically selected signals emerge from that point, and there will ordinarily be less than three video signals on any individual wire (as described in more detail below). By protecting that convergence point, therefore, fewer signals are available for piracy than in the case where coaxial cables reach all the way to the television. Because easy, surreptitious access to the convergence point will not be available when the point is on a utility pole or in the basement of an apartment building, piracy from the twisted pair distribution system of this invention is even more difficult.

The general principles and techniques described in the parent and first and second CIP applications include some of the ingredients useful to enable converging telephone lines to carry video and other signals from a point of convergence to the individual local networks (i.e. houses, apartment units, rooms in office buildings) in addition to carrying the telephone signals. Problems can arise, however, due to the unusually long path length of the wire branch leading between the point of convergence and the internal telephone network within a residence. Other problems can arise because the wire pairs from neighboring subscribers are often tightly bundled near the point of convergence. This may cause a signal from one wire pair to be picked up by a neighboring pair in the bundle, causing interference. Finally, provision must be made for selection of cable TV channels from within each residence. One of the objects of this invention is to overcome these problems.

Using active telephone wiring as the transmission line for wideband signals (e.g., cable TV signals) leading from a main telephone trunk line to the individual subscribers can also improve upon communication systems other than those used to distribute ordinary cable TV. One example is the "video on demand" system described above. A shortcoming

of the typical video on demand system is the coding and decoding (i.e., scrambling and unscrambling) that must be provided at each end of the transmission line. Another drawback is that the excess capacity on cable trunks carrying cable TV signals is typically very limited. If, for example, a cable TV franchise provides signals up to cable channel 63 (which extends between 462 Mhz and 468 Mhz), the "video-on-demand" signals are restricted to the frequencies above that. Using higher frequencies may be undesirable because the attenuation of the cable increases with increasing frequency, and most cable converters are not designed to extend that high. If the existing cable can transmit signals up to, for example, 600 Mhz, then only 132 Mhz, or the equivalent of twenty-two 6 Mhz AM channels, are available above channel 63 at each neighborhood. In this situation, at most 22 houses per neighborhood can receive video on demand.

Telephone wiring from a centralized location (such as the point of convergence discussed above) can be useful because it can replace the coaxial cable as the conductor leading from the cable trunk (e.g., the high-capacity fiber optic line) to the individual residences. One advantage of telephone wiring is that it provides a dedicated path from the point of convergence to each subscriber. This means that signals on the optic fiber line that are "handed-off" onto an individual wire pair transmit to only one subscriber. This eliminates the need for scrambling which is otherwise necessary when many subscribers receive a signal (such as over a shared coaxial cable TV network) that only a limited group of them pay for.

A disadvantage, mentioned above, is that such a point of convergence at which conductors lead to a large number of subscribers is not always nearby. If some of the subscribers are a great distance from the convergence point, the attenuation of transmission may be too severe to allow reliable communication across the twisted pairs that comprise the telephone line.

This problem is less severe in the case of the residential units in an apartment building. Because these buildings typically consist of many units whose telephone wire pairs usually converge at a nearby point, such as when a "wiring closet" is provided for each floor, their telephone lines are particularly good candidates for providing this type of communication. Usually, there is a point in the basement of such buildings where the wiring from all units on all floors converges.

Commercial buildings also include locations where many telephone lines converge. Often, the individual wires leading to the various rooms of the building converge at what is called a "PBX," or private branch exchange. Such an exchange is provided because considerable communication between rooms is required that is not, of course, economically provided by the public telephone exchange.

As mentioned earlier, the popularity of teleconferencing has created a demand for video distribution within an office setting. Often, videoconferencing allows for a group of workers in a building to monitor a conference at a remote location. This requires one-way communication of video. Other forms of video conferencing, however, require two-way video communication. Using telephone wires for these purposes is more complicated, of course, because at least two video signals must transmit in opposite directions. One solution, proposed herein, is to use more of the frequencies, or spectrum, available on each wire pair. Another is to use a different wire pair in the same bundle leading to each office, if it is available. Each of these causes special

problems, as will be described herein. One of the objects of this invention is to overcome the problems associated with two-way communication of video across the telephone wires in an office building.

Because of the considerable communication demand between rooms in an office setting, a demand has also arisen for two-way video communication between rooms in the office. A difficulty in using the telephone wiring for transmission of video across that setting is that the conductive paths between the various offices are broken by the PBX. In the first parent application, a technique to provide a high frequency "bridge" between the various wires leading to a PBX was described, thus making the various wires appear, at high frequencies, as a single conductive path. In this application, that technique is expanded upon to provide switching of video between offices, and simultaneous communication of more signals.

In many office buildings, the telephone wiring is not the only network of twisted pair wiring that extends to each office and converges at a common point. Over the past several years, common communication networks that connect personal computers, known as Local Area Networks or LANs, have begun to use twisted pair wiring for their conductive paths. In the typical configuration, a digital electronic device serves as the "hub" for such a system, and a separate twisted pair wire connects from this center to each of the computer nodes. Transmission of video across this medium involves the same problems encountered in transmitting across a PBX system. Additionally, extra difficulties are encountered because the signals that "naturally" transmit across the system, i.e. the digital computer signals, occupy a much wider band than telephone signals. In this application, the technique for communication across a PBX is expanded to provide the same capabilities for wiring networks that provide the conductive paths of a computer local area network (LAN).

In addition to video distribution to houses and apartment units and video communication within office buildings, there is a fourth communication system that can be improved upon by distributing video signals over multiple pairs of telephone wires. This system is the main public telephone network itself. The copper wires of this network are currently being replaced by fiber optics because these lines can carry much more information. Increasing the communication capacity to an individual residence using current technology requires installation of a fiber optic cable spanning the entire distance from the "local exchange" to the residence. The improvement described herein is the result of using the existing copper wires to communicate video and other signals over approximately the last 1000 feet of this link, i.e. from the main optical fiber trunks to electronic devices in subscriber facilities. This eliminates the need to install a new communication line between each residence and the main trunk. It also eliminates the need to adapt each electronic device in a residence to receive optical signals.

A new development in video communication colors the entire concept described so far. The new development is the advent of techniques that digitize and compress standard commercial video signals (such as NTSC or PAL) in real time, without reducing information content, so that the resultant digital bitstream has a data rate that is slow enough to be expressed as an analog waveform in a remarkably narrow channel. This development presents the possibility that considerable programming will be transmitted in this form in the near future.

Accordingly, it is seen that the present invention provides a technique for one-way distribution of signals of a general nature that require bandwidths much wider than the 3 Khz voiceband currently in use. These signals are transmitted to multiple local networks of active telephone wiring, (i.e. the telephone wiring systems of several houses, apartment units, or rooms in an office building) from a signal source at a location where the active telephone wires leading to the residences converge. In the typical application this signal source will be a "tap" into high capacity communication link such as a fiber optic transmission line or a coaxial cable.

The interface provided by the invention includes a transceiver/switch located at the point of convergence. This device replaces the existing interface between the public telephone network (i.e., an ordinary telephone trunk line) and the telephone lines that lead to the individual residences. (These telephone lines are referred to below as "extended twisted pairs".) Typically, the existing interface will be a simple "punch-down" panel that provides electronic connections between the extended pairs and the pairs that are part of the trunk line. The transceiver/switch receives multiple signals (such as several channels of cable TV signals) from the high-capacity communication link such as a coaxial cable or fiber-optic line, and selectively switches these video signals onto the individual phone lines, together with the phone signals. Means are provided at each individual network (i.e. the internal telephone wiring of each residence) to receive and separate these signals.

In addition, the invention allows each subscriber to control the signal selection by the transceiver/switch in situations in which a large group of signals on the high capacity communication link is made available for selection by any subscriber. Control (e.g. channel selection) is established by sending signals from a local network to the transceiver/switch over the extended twisted pair telephone lines, e.g., in the reverse direction from the direction of transmission of the selected video signals. A particularly appropriate application for such a system is as an alternative method of distributing cable TV service.

The invention also provides two-way communication of signals of a general nature with the high capacity transmission line. This allows the user to transmit wideband (e.g. 5 Mhz) signals of an arbitrary nature (such as video signals and high data rate computer signals) over the extended twisted pairs from the user's residence to the transceiver/switch, so that the transceiver/switch can add them to the high capacity transmission line for communication with, for example, a receiver at the point where signals transmitting in the "forward" direction originate (e.g., the video library discussed above.) The invention further provides two-way switched video communication between the local networks (e.g. the rooms) in office buildings and in other buildings that have requirements for two-way communication.

Moreover, all of the communication capabilities discussed above can (and preferably do) use networks of twisted pair wiring that are also used for computer communications.

The communication techniques of the present invention can be adapted to provide the same capabilities when the signal source at the point of convergence provides video signals expressed as analog signals representing compressed digital bitstreams.

It is important to note that this invention provides the video signal communication capabilities described above while preserving all of the features of the pre-existing telephone and computer communications. Thus, interference on the telephone lines between ordinary telephone communications and the selected video signals is avoided.

As discussed above, the interface includes a transceiver/switch that is connected to multiple pairs of telephone wiring and is interposed between telephone wire pairs from the local telephone exchange (the trunk line) and the extended telephone wire pairs leading to separate local networks of telephone wiring. The transceiver/switch also connects to a link used for long distance communication of many multiple signals, such as TV signals.

The invention also includes RF transmitters and RF receivers (described in detail in the parent and first and second CIP applications) that are connected to the telephone wiring of the local networks and a local network interface device disposed between the local network wiring and the extended twisted pair wiring that leads to the transceiver/switch. These elements cooperate to provide the following results:

1) The transceiver/switch can select any one of the signals provided by the high-capacity communication link and transmit it along the extended wire pair leading to any one of the local networks. At least one video signal can be sent to every local network at one time.

2) Normal telephone communication on all local networks and between the local networks and the public network (trunk) is preserved. All pre-existing computer communication capabilities are also preserved.

3) A signal transmitted from the point of convergence will be received by the local network interface and retransmitted onto the local network, making it available for reception by an RF receiver connected at any point on the local network. (In some embodiments, a local network interface is not included and signals transmitted at the point of convergence transmits directly onto the local network for reception by a video receiver connected thereto.)

4) Any RF transmitter connected to a local network can transmit a signal to the transceiver/switch by transmitting that signal onto the local network. A signal sent in this manner is received by the local network interface and retransmitted onto the extended twisted pair wire. (In some embodiments, a local network interface is not included and a signal applied to a local network by an RF transmitter is transmitted directly to the transceiver/switch without interception and retransmission.) At least one video signal from each local network can be transmitted in this direction at the same time.

5) Any RF video receiver on a local network can detect control signals from infrared transmitters (e.g., hand-held remote control devices typically used to control the operation of televisions, VCRs, etc.) and transmit them to the transceiver/switch, allowing the user to control program selection at the transceiver/switch from the location of, e.g., any television connected to the local network through an RF receiver.

6) In addition to selecting any one of the signals provided by the high-capacity communication link for transmission along the extended wire pair leading to any one of the local networks, the transceiver/switch can also select any of the video signals received from one local network for transmission to any other local network.

Other features and advantages of the invention will become apparent from the following detailed description, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1*a* is a block diagram showing the placement of the transceiver/switch and local network interfaces in a system of telephone lines leading to multiple local networks according to one aspect of to the invention.

FIG. 1*b* is a block diagram showing the placement of the transceiver/switch of FIG. 1*a* between a PBX ("private branch exchange") and the system of telephone lines leading to different rooms in an office building according to another aspect of the invention.

FIG. 2 is a functional block diagram of the transceiver/switch of FIGS. 1*a* and 1*b*.

FIGS. 3*a*–3*c* show different spectral distributions of video signals that are useful in understanding the invention.

FIG. 4 is a block diagram of a processor in the transceiver/switch of FIG. 2.

FIG. 4*a* shows additional details of a component of the processor of FIG. 4 that serves as an interface to the high capacity communication line.

FIG. 5*a* shows another component of the processor of FIG. 4 that performs the distribution of signals to the various local networks.

FIG. 5*b* shows an alternative embodiment of the component of FIG. 5*a* that allows transmission of signals from one local network to a different local network.

FIG. 5*c* shows another alternative embodiment of the component shown in FIG. 5*a*.

FIG. 6*a* shows additional details of still another component of the processor of FIG. 4 that performs the reception and disposition of signals sent from the various local networks.

FIG. 6*b* shows an alternative embodiment of the component of FIG. 6*a*.

FIG. 7 is a block diagram of a control signal processor in the transceiver/switch of FIG. 2 for processing the signals sent from the local networks to control signal selection and other processing at the point of convergence.

FIG. 8 is a table that summarizes the signals transmitted across the extended pairs in one of the examples used in the disclosure.

FIGS. 9*a* and 9*b* are block diagrams of embodiments of a signal separator in the transceiver/switch of FIG. 2, showing the electronics that route signals onto multiple extended pairs, route signals received from each extended pair, and process the telephone signals on the extended pairs.

FIG. 10 illustrates one embodiment of a local network interface of FIG. 1*a*.

FIGS. 11*a*–11*c* show additional details of various embodiments of components of the local network interface of FIG. 10 that process the non-telephone signals transmitting between the local networks and the transceiver/switch.

FIG. 12 shows one of the RF processors (described in the second CIP application) that performs part of the function of the local network interface of FIG. 10.

FIGS. 13*a* and 13*b* show additional details of the components of the local network interface of FIG. 10 that processes the telephone signals transmitting between the local networks and the transceiver/switch.

FIG. 14 shows additional details of a wiring closet booster that includes several local network interfaces for boosting the levels of signals transmitting in both directions between the transceiver/switch and several of the local networks.

FIG. 15 is a block diagram of a digital video receiver useful with the systems of FIGS. 1*a* and 1*b*.

FIG. 16 shows another embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A. Overview (FIG. 1*a*)

Referring to FIG. 1*a*, the technology described in this application is designed to communicate signals between transceiver/switch **400**, located where individual telephone lines from multiple local networks converge for connection to a main telephone trunk **476'**, and groups of RF communication devices that are connected to the individual local networks **411***a*–**411***e* of telephone wiring. Each of local networks **411***a*–**411***e* (collectively "local networks **411**") includes the wiring confined to a structure such as a house or to an area within a structure such as an apartment unit or a room in an office building. This wiring provides a single conductive path for a single ordinary telephone signal. Thus, in the case of the common four conductor telephone wiring, the red/green pair constitutes one local network, and the yellow/black pair constitutes a second local network. (The only special relationship between these local networks is that they bundle more tightly together than wiring serving different areas. Theoretically, this could increase the crosstalk between the pairs.)

Note that the details of the wiring of local networks **411***d*, **411***e* are not shown in FIG. 1*a*. Those local networks will not be served by the communication system described herein. They are included only to demonstrate that not all local networks within a group whose wires converge at a particular point need participate in the communication system described herein.

The wiring of each local network further includes a single branch that strays far from the structure, ultimately leading to the point of convergence where they connect to (or become part of) trunk **476'**. These are extended pairs **405***a*–**405***e*, (collectively, extended pairs **405**.) The extended pairs **405** from each of local networks **411** may be bundled closely together near the point of convergence.

When transceiver/switch **400** is installed, extended pairs **405** are broken near the point of convergence, with transceiver/switch **400** interposing between the two ends of each pair. One segment of each pair remains connected to trunk **476'**. These segments are called twisted pairs **476***a*–**476***e*, (collectively, twisted pairs **476**.) Thus, twisted pairs **476** and their associated extended pairs **405** ordinarily constitute an uninterrupted connection between local networks **411** and local telephone exchange **475**. In the system described herein, transceiver/switch **400** interposes between these wires to provide a link between communication line **402** and local networks **411**. As will be described below, one of local network interfaces **404***a*–**404***c* may also interpose along this path, in the middle of or at the opposite end of the corresponding one of extended pairs **405**.

Communication line **402** provides high capacity communication (such as for cable TV signals) with remote locations. Line **402** includes one or more coaxial cables, optical fibers, or the like. Transceiver/switch **400** connects to line **402** to receive and transmit signals. It processes the signals it receives, and switches them onto selected ones of extended wire pairs **405** leading to local networks **411**, together with (and without interfering with) the telephone signals (e.g., voice signals) that also use those wires. The switched signals are received by the RF communication devices connected to local networks **411**.

Transceiver/switch **400** also receives video, digital, control, and other types of signals from extended pairs **405**. These signals, which normally originate in the areas served by the local networks **411**, are applied to local networks **411** by the connected RF communication devices, and transmit across extended pairs **405** to transceiver/switch **400**.

Local network interfaces **404***a*–**404***c* (collectively, interfaces **404**) are respectively interposed on extended pairs **405***a*–**405***c*, thus connecting between transceiver/switch **400** and the corresponding local networks **411**. Typically, they will be located at a part of extended pairs **405** that is closer to the corresponding local network **411**, rather than transceiver/switch **400**. They assist in the transmission of signals in both directions between transceiver/switch **400** and local networks **411**, as described in more detail below.

Each local network interface **404** intercepts signals sent from the corresponding extended pair **405**, applies amplification and/or other signal processing, and feeds the resulting signal onto the corresponding one of local networks **411**. This assists in the transmission between transceiver/switch **400** and local networks **411**. Each local network interface **404** also performs a similar function to assist signals that are transmitted in the other direction, i.e., by receiving signals from one of local networks **411** for transmission to transceiver/switch **400** via one of extended pairs **405**.

As is emphasized at several points in this document, local network interfaces **404** need not be used in some conditions, particularly when extended pairs **405** are relatively short, e.g., less than 300 feet in length. Such is often the case in apartment buildings. This is fortuitous because there is often no opportunity to interpose a device between the point of convergence and the telephone jacks in an apartment unit when a transceiver/switch is located in the wiring closet on each floor of the building. (When the point of convergence is a room in the basement where all the twisted pairs converge, the wiring closets are good locations for local network interfaces, as is described in greater detail below. A communication system is shown in FIG. 1*b* and described later on that does not include local interfaces **404**.)

The communication devices connected to local networks **411** are now described. Video receivers **419***a*–**419***c* and **419***a'*, video transmitters **417***b*–**417***c*, digital transceiver **491***c4c*, and telephone devices **414***a*–**414***c* (collectively, telephone devices **414**) all connect to local networks **411***a*–**411***c* as shown in FIG. 1*a*. Except for telephone devices **414**, all of these devices communicate RF signals over local networks **411**, and are referred to herein as RF transmitters and RF receivers. The RF signals they apply to local networks **411** are received by local network interfaces **404** and retransmitted across extended pairs **405**. (These signals can also be received by other devices connected to local networks **411**.) Any number of RF transmitters and receivers and telephone devices can connect to any one of local networks **411**.

Each of telephone devices **414** connects via a low-pass filter (LPF). As described in the first CIP application, these filters prevent telephone devices **414** from affecting RF energy on the local networks **411**. These filters may be provided as part of splitter **161**, which is described in the first CIP application.

The video transmitters and receivers are those described in the parent application and in the first and second CIP applications. Video receivers **419***a*–**419***c* and **419***a'* (collectively, video receivers **419**) connect to televisions **492***a*–**492***c* and VCR **498***a*, respectively. Video receivers **419** also detect infrared (IR) light signals, convert them to equivalent electrical signals, and apply them to the corresponding one of local networks **411**. These signals transmit across extended pairs **405** to transceiver/switch **400** for purposes described in detail below. Infrared transmitters

493*a*–493*c* (collectively, infrared transmitters 493), are respectively provided at local networks 411*a*–411*c* to produce the IR signals.

Video transmitter 417*b* connects to video camera 494*b*. It derives a video signal from that device, processes the signal, and applies it to network 411*b*. Camera 494*c* connects to video transmitter 417*c* which connects to local network 411*c* and operates in a similar manner. Transmitters 417*b* and 417*c* also receive the control signals applied to their associated local network 411. They convert these signals to infrared signals equivalent to the original signal, then broadcast them out into the vicinity for reception by nearby infrared responsive devices.

Digital transceiver 491*c* connects between a computer 495*c* and local network 411*c*. It receives digital signals from the network wiring and transmits them to computer 495*c*, and it also receives signals from computer 495*c* and applies them to the wiring. Digital transmitters and receivers are described in the first CIP application. That application also describes how to combine RF transmitters and receivers into a single device that communicates through a single connection to active telephone wiring.

Except for control signals meant to communicate with transceiver/switch 400, the non-telephone signals received from extended pairs 405 by transceiver/switch 400 are fed to line 402 for transmission to other communication devices that connect to line 402 at locations removed from transceiver/switch 400. One application for this is to establish a simple two-way videoconference between two people located near opposite ends of communication line 402 or at two points of line 402 that are far from each other.

In the reverse direction, transceiver/switch 400 can transmit any of the signals (such as cable TV signals) selected and recovered from communication line 402 over any one of the extended pairs 405, without disturbing the telephone signals that also use those wires. A single selected signal (e.g. an ordinary NTSC television signal) can be assigned to more than one pair, and several signals can be assigned to the same pair.

The processing performed by transceiver/switch 400 on the signals it recovers from communication line 402 converts those signals to the waveform (e.g. the modulation type such as AM or FM) energy level, and frequency band at which they will be effectively transmitted onto wire pairs 405. These signal characteristics must be such that the signals will communicate with high fidelity over extended pairs 405*a*–405*c* to the RF communication devices connected to local networks 411*a*–411*c*. The relationship between these signal characteristics and the success of this communication is discussed at length below.

The selection of the signals from line 402 and their assignment to particular ones of extended pairs 405*a*–405*c* (and thus their assignment to the various local networks 411*a*–411*c*) is made by transceiver/switch 400 in response to the control signals sent from local networks 411 over extended pairs 405. Transceiver/switch 400 also receives and responds to control signals from communication line 402, which can give the originator of those signals partial control over signal distribution to local networks 411.

The signals from local networks 411 to which transceiver/switch 400 responds in making selections are known as "control" signals and are sent by subscribers using infrared transmitters 493. Using techniques partly described in the parent and first and second CIP applications, video receivers 419 detect these infrared signals, convert them to electrical signals and apply them to local networks 411. These signals then transmit to transceiver/switch 400, as is described below. Control signals from local networks 411 can also be generated by other means, and applied to local networks 411 by other RF communication devices. The digital transmitters described in the first CIP application, for example, can respond to manual inputs to transmit an electrical signal (representing binary information) onto local networks 411. This electrical signal can be used to communicate a channel selection to transceiver/switch 400.

Following is an example of how this system is used to communicate video and control signals. First, assume communication line 402 conveys 30 video signals from a local cable TV franchise. According to the invention, transceiver/switch 400 selects one or more (typically one or two) video signals from among those 30 to be sent to, for example, local network 411*a*. Transceiver/switch 400 transmits the selected video signals over extended pair 405*a* to local network interface 404*a*. Interface 404*a* receives these signals and retransmit them onto local network 411*a*, where they will transmit to video receivers 419*a* and 419*a*' and be provided to TV 492*a* and VCR 498*a*. Other RF receivers that connect to local network 411*a* can also receive these signals.

Viewers of television 492*a* connected to local network 411*a* via video receiver 419*a*, meanwhile, can use transmitter 493*a* to issue infrared control signals to determine which signals are selected and transmitted to local network 411*a*. Video receiver 419*a* detects these infrared patterns, converts them to electrical signals, and applies them to local network 411*a*. These electrical signals are received by local network interface 404*a* which processes them and relays the signal across extended pair 405*a* to transceiver/switch 400. These signals indicate to master controller 415 (FIG. 2) the identity of the cable TV signals that are to be sent to local network 411*a*. Alternatively, signals from communication line 402 detected by master controller 415 can also determine the identity of the cable signal to be sent to local network 411*a*.

The viewer can also transmit video signals from a local network 411 to communication line 402. This can be useful for any number of purposes, the most simple of which is to add pictures to an ordinary two-way telephone conversation. An example of this is where the signal from video camera 494*b* is applied to local network 411*b* by video transmitter 417*b*. That signal will transmit over local network 411*b* to local network interface 404*b*. Local network interface 404*b* receives the video signal and transmits it across extended pair 405*b* to transceiver/switch 400 which will apply the signal to communication line 402. (Again, local network interface 404*b* will facilitate this communication only if it is included in the system.) There can be a large variation in the lengths of extended pairs 405. In an apartment building, the telephone wires serving different units may converge at a point 100 feet or less from each apartment unit. An example of the other extreme occurs when distributing signals to separate houses in a neighborhood. In this case, connecting ten houses to the a single transceiver/switch 400 may mean that some of extended pairs 405 will be longer than, perhaps, 1000 feet.

Unfortunately, attenuation of the video signals increases with frequency, which means that the highest useful frequency on extended pairs 405 decreases with length, ultimately restricting the signals to below 4 Mhz. This is a problem because 4 Mhz of bandwidth is the approximate minimum required for transmission of an NTSC video signal in analog form. The inventors estimate that this point occurs before the lengths of extended pairs 405 reach 3000 feet.

The solutions described herein take advantage of the improved ability of RF (radio frequency) signals to transmit

over longer distances at lower frequencies to avoid problems due to the lengths of extended pairs **405**. The invention also takes advantage of the property of conducted RF transmission that dictates that the tendency for energy from a signal on one wire pair to cross over to a neighboring pair decreases as the frequency of the signal decreases. This crossover, which can cause interference, is likely to result when pairs **405** are closely bundled within a common sheath, as often happens. Finally, the ability of frequency modulated (FM) signals to resist interference to a greater degree than amplitude modulated (AM) signals with more narrow bandwidths also plays a part in the system design.

The next part of the disclosure describes the signal flow between major components internal to transceiver/switch **400**, and the processing performed by those components. That section is entitled "Signal Flow and Signal Processing in Transceiver/Switch **400**." One of the major goals of this processing is to convert signals from the form provided by communication line **402** to the waveform, frequency band, and amplitude useful for successful communication across one of the extended pairs **405***a*–**405***c*. The requirements for these characteristics are described in the section entitled "Transmission of Wideband Signals Over an Extended Pair."

Two other sections following are entitled "Signal Conversion and Switching in Transmitter/Switch **400**" and "Transmission and Recovery of Signals from a Single Twisted Pair in a Bundle." Details of major processing components of transceiver/switch **400** are provided therein. Finally, details of signal processing with in local network interfaces **404** is described in the last section, which is entitled "Signal Processing at the Local Network Interface.

B. "Signal Flow and Signal Processing in Transceiver/Switch **400** (FIG. 2)

Following is a description of a general embodiment of transceiver/switch **400**. Referring to FIG. 2, the major processing elements of transceiver/switch **400** are processor **418**, signal separators **413***a*–**413***c* master controller **415**, low pass filters **474***a*–**474***c*, and control signal processor **420**. Processor **418** serves as the interface to communication line **402**, and each signal separator **413***a*–**413***c* (collectively, signal separators **413**) serves as the interface to the corresponding one of extended pairs **405**. One of the functions of processor **418** is to select, under the direction of master controller **415**, video and other signals from communication line **402**, to process those signals, and to feed them to signal separators **413**. Another function of processor **418** is to receive video and other signals from signal separators **413**, convert those signals to a form appropriate for transmission on line **402**, and feed them to communication line **402**. A third function is to receive signals from any given one of signal separators **413**, convert those signals, and to feed them to a different one of signal separators **413**, thus establishing communication from one of local networks **411** to another.

Each of signal separators **413** is connected between one of extended pairs **405** and the corresponding one of twisted pairs **476**. One of the two major functions of each of signal separators **413** is to transmit signals from processor **418** onto one of extended pairs **405**. These signals are applied so that they transmit onto extended pairs **405** in the direction of local networks **411**. A second purpose of each of signal separators **413** is to recover signals transmitting from one of local networks **411** over the corresponding one of extended pairs **405**, and to provide these signals to processor **418**. In some embodiments, signal separators **413** also convert telephone signals so that they transmit over extended pairs **405** at frequencies above voiceband.

Each of twisted pairs **476** connects to the "exchange" port of the corresponding one of signal separators **413**. In FIG. 2, the "exchange" port is on the left side of signal separators **413**, and the "local" port is on the right side. Signals provided by processor **418** to signal separators **413** transmit out the "local" port onto one of extended pairs **405** towards the associated one of local networks **411**. Signals transmitting from local networks **411** to transceiver/switch **400** flow in the opposite direction. The various ports of signal separators **413** are shown in more detail in FIG. 9*a*. The details of signal routing within signal separators **413** are described below.

In contrast to the "local" port, only telephone signals flow through the "exchange" ports of signal separators **413**. Telephone signals transmit over twisted pairs **476** in both directions, transmitting between local exchange **475** and the "exchange" ports, thus passing through low-pass filters **474***a*–**474***c* (collectively, low pass filters **474**) during transmission.

Low-pass filters **474** connect in series on twisted pairs **476** to suppress the higher harmonics of telephone signals transmitting across them. This suppression prevents the higher harmonics of the telephone signals from local exchange **475** from reaching extended pairs **405**, where they could possibly interfere with RF signals.

Signal flow between signal separators **413** and processor **418** is now described. There are two conductive paths connecting processor **418** with each of signal separators **413**. Paths **478***a*–**478***c* (collectively, paths **478**) conduct signals transmitted by processor **418**, and paths **479***a*–**479***c* (collectively, paths **479**) conduct signals transmitted by the associated one of signal separators **413**.

The electrical signal, i.e. the voltage variations transmitted to each one of signal separators **413** from processor **418**, may include several individual signals at different frequencies that are combined together onto the associated one of conductive paths **478**. In response to commands sent from master controller **415**, processor **418** determines the composition of each of these combined signals. After transmission to a particular one of signal separators **413**, each combined signal continues on to transmit to the corresponding one of extended pairs **405**.

Other than switching and filtering, no processing of the combined signal takes place after it leaves processor **418** until it reaches one of local network interfaces **404**. Thus, the signal processing performed by processor **418** on the individual signals it selects and recovers from communication line **402** determines the waveform (e.g., AM or FM), frequency, and amplitude at which these individual signals are transmitted across pairs **405**.

In the reverse direction, signals transmitted by RF transmitting devices **417** onto one of local networks **411** transmit to the corresponding one of signal separators **413**. (Other devices can also transmit RF signals onto one of local networks **411**. An example is any of video receivers **419**, which transmit control signals.) The corresponding one of signal separators **413** recovers these signals and, except for control signals targeted for master controller **415**, feeds them over the associated one of paths **479** to processor **418**. These signals are received by processor **418** and applied to communication line **402**. They may also be transmitted to any of local networks **411** that are different from the local network **411** of origin.

Control signals originated by subscribers are fed to local networks **411** within a specific frequency band, and are transmitted to master controller **415**, as described below.

This provides a method of communication between a subscriber and transceiver/switch **400**, allowing the subscriber to control, among other things, the channels that are selected from communication line **402** for transmission to the local network **411** where the control signal originated. In a preferred embodiment, these signals are issued by an IR device **493** as infrared patterns which are detected by video receivers **419**, converted to electrical signals, and fed onto the wiring. Other systems of feeding signals onto local network **411** within the particular frequency band can also suffice.

The control signals targeted for master controller **415** are received from local networks **411** by local network interfaces **404** which process them and apply them to extended pairs **405**. These signals are recovered from pairs **405** by signal separators **413** and fed over the associated one of paths **477***a*–**477***c* (collectively, paths **477**) to control signal processor **420**. Processor **420** processes these control signals and communicates them over path **420***a* to master controller **415**.

Master controller **415** also receives (via control signal processor **420**) control signals that processor **418** recovers from communication line **402** and sends over path **420***b*. In response to these signals and to the control signals it receives from local networks **411**, master controller **415** sends signals to processor **418** over links **446***a*–**446***e* (collectively, links **446**). Processor **418** determines the selection of signals from communication line **402** and the composition of the signals fed over extended pairs **405** to local networks **411** in response to signals from links **446**.

C. Transmission of Wideband Signals over an Extended Pair

As described above, processor **418** selects signals from communication line **402** and converts them to the waveform, frequency, and energy level at which they are fed to extended pairs **405**. These characteristics determine, to a large extent, the ability of video receivers **419** connected to local networks **411** to detect these signals and the ability of extended pairs **405** to conduct more than one signal at a time.

The nature of the communication medium that is the subject of this application presents two particular problems. One problem is that there is a significant possibility of crosstalk interference between the various signals on extended pairs **405**. This possibility is high because telephone wires converging at a common point may run parallel and very close to each other for a long distance. This makes interference resulting from crossover of RF energy between the pairs likely. A second problem is that the usefulness of the system is related to the length of the longest path over which communication can succeed. This is a problem because communication bandwidth decreases as the length of a twisted pair communication line increases. (The issue of transmission length will be less important for communication within apartment houses and office buildings than they will be for communication with separate residential structures in a neighborhood. This is mostly because the wires of many different networks in an apartment or office building often converge at a point less than 500 feet from those networks.)

In addition to these problems, there are also particular advantages to this medium. In particular, because extended pairs **405** connect directly between transceiver/switch **400** and local network interfaces **404**, these wires encounter no splits and no connected telephone devices. Thus, signal splitting does not cause problems on extended pairs **405**, and connected telephone devices will also not have an influence on transmission over those pairs.

The parent and first and second CIP applications describe many of the relationships between the properties of a signal and its tendency to be attenuated and distorted during transmission across telephone wiring. As described therein, the maximum transmission length increases with decreasing frequency because of improvements in transmission characteristics. Specifically, attenuation, radiation, and the ability of the wiring to pick up (interfering) broadcast energy all decrease as transmission frequency is reduced. Also, crossover of energy between neighboring pairs decreases with decreasing frequency. Those applications also discuss spectral tilt, another undesirable byproduct of transmission over telephone lines.

The first CIP application explains that FM video signals have a greater noise immunity than do AM video signals, i.e., the SNR after demodulation of an FM signal is higher than that of AM video signals if the frequency modulation process creates a signal with a wider bandwidth than the AM signal. As explained in the first CIP application, the sensitivity advantage of FM video signals over AM increases as the bandwidth of the FM signal increases.

The ability of FM signals to reject interference increases when the interfering signal is a second FM signal confined within the same channel. As explained in the first CIP application, the minimum energy advantage that a receiver requires to reject a weaker but otherwise equivalent signal in the same channel is known as the "capture ratio", and is often significantly less than the minimum SNR necessary to avoid distortion by white noise. The exact capture ratio will depend on several factors, but the inventors estimate that the "capture ratio" of an FM NTSC video signal with a 15 Mhz wide bandwidth will typically be less than 10 db, allowing it to ignore interfering FM signals whose levels are suppressed by at least 10 dB.

Using FM to transmit video has three disadvantages, however. One is that the tuning circuitry of common television sets expects to receive AM signals. This means that an extra signal conversion may be required before a picture is generated. Secondly, FM video electronic circuitry is more expensive. The third disadvantage is that a group of adjacent FM video channels will cover a wider band than a group of adjacent AM channels. In addition to occupying more spectral area, a band of adjacent FM channels will reach higher frequencies than a band of the same number of adjacent AM channels (assuming that both bands begin at the same frequency). Signals transmitting over FM channels, therefore, will generally suffer more from the problems associated with increasing frequency.

When processor **418** transmits several signals simultaneously across one of extended pairs **405**, it assigns each signal to a separate frequency band, or channel. The energy of each signal will be confined within that band. (Effectively, this "channelizes" that particular extended pair **405**.) Additionally, processor **418** determines the waveform and energy level of each individual signal. On the basis of the considerations described above, a set of guidelines have been developed to aid in determining these characteristics for a given communication scenario. Some of the guidelines apply to transmission of signals of a general nature. Other guidelines will apply only to television signals. Still others will apply only to the specific situation of the communication of one or two video signals over especially long distances. These guidelines are disclosed in the following paragraphs (1–6).

1) Energy Level

Because RF signals that may be transmitted across telephone lines are relatively low in power, increasing signal

level is not likely to cause a significant increase in cost, and is also not likely to cause problems of safety. Furthermore, maximizing the signal levels maximizes the SNR at the receiver. Thus, there are no benefits to lower signal levels, and the signal level should be set so that the resulting radiation falls just below governmental limits on the airborne radiation.

Because telephone wiring is unshielded, EMF radiation will result no matter how well the transmitting or receiving devices are shielded. Thus, these radiation levels will not significantly vary with any factor other than the signal level. This means that the radiation can be determined at the time of manufacture, avoiding the expense of providing for adjustable signal levels.

For example, following FCC procedures, the inventors fed a 22.45 Mhz NTSC video signal onto a telephone wire and measured the resulting radiation. It was found that at a conducted signal level of approximately 50 dB mV, radiation from the wire would be just below the governmental limits of 30 uV/M measured at 30 Meters. Thus, a level of 50 dB mV would be preferred for a transmitter that applies a 22.45 Mhz video signal to telephone wiring.

2) Adjacent Low-Frequency Channels

As described above, attenuation, radiation, crosstalk interference and reception of external interference all increase as frequency increases. This means that the signal with the highest frequency is most likely to have the lower SNR, and that overall communication success can be improved by lowering the frequency below which all signals are confined.

To minimize the highest frequency used for transmission, it is recommended that the first channel be placed as close to the voiceband as feasible, and that each succeeding channel be placed above and adjacent to the previous channel. The channels should be separated in frequency sufficiently, however, to allow clean separation at the receive end without excessive filtering costs.

3) Minimum Frequency

If AM is used to transmit video signals, it is preferred that the picture carrier of the first such channel be located above 4.25 Mhz. This frequency is chosen as a rough compromise between the following factors: a) transmission properties improve with lower frequencies; b) as described in the first CIP application, the likelihood of distortion of AM signals caused by the phenomena of spectral tilt increases with decreasing picture carrier frequency below 5 Mhz; and c) there are certain advantages in arranging for transmission of several adjacent 6 Mhz AM NTSC video signals beginning with a signal whose picture carrier is at 4.45 Mhz. (One major advantage, which is described more fully in the second CIP application, is that arranging video channels in this manner reduces the likelihood of interference from amateur radios.) For FM transmission, it is preferred that the low end of the first channel be 4 Mhz. This frequency is chosen as a rough compromise between the following considerations:

a) Transmission properties improve at lower frequencies;

b) Spectral tilt becomes more pronounced with increasing ratios between the highest and lowest frequencies of an FM signal. (the problem of the spectral tilt of FM signals is described in the first CIP application);

c) lowering the low end of an FM band by 1 Mhz does not provide a significant decrease in the percentage reduction of the frequency of the high end. For example, moving the low end of a 15 Mhz channel from 3 Mhz to 2 Mhz only reduces the upper frequency by 5%, i.e. from 18 to 17 Mhz.

4) Bandwidth

Assume that "N" different signals are to be transmitted within adjacent channels, that the average width of the channel confining a signal is B Mhz, and that the low end of the lowest channel is k Mhz. Under these conditions, the high end of the channel highest in frequency is given by (Nb+k) Mhz. Thus, decreasing bandwidth decreases the maximum frequency.

Because of this, a preferred system when transmitting multiple NTSC video signals is to provide all signals using AM modulation within 6 Mhz channels distributed according to the NTSC standard. (I.e. a picture carrier 1.25 Mhz above the low end and a sound carrier 0.25 Mhz below the high end.) This arrangement is chosen because the bandwidth is relatively narrow, yet separation can be achieved using inexpensive filtering. This is the same arrangement that was chosen for airwave transmission of video shortly after the invention of television. The same justifications applied. Because of that standard, very inexpensive electronics exist for this type of channeling, providing another advantage.

The preferred lower end for the band of transmission over extended pairs **405** is defined by an AM signal with a picture carrier of 4.45 Mhz. (The lower end of an NTSC video channel with a carrier of 4.45 is at 3.2 Mhz. This is because the bottom of the 6 Mhz channel is 1.25 Mhz below the picture carrier.) The advantages of providing adjacent AM signals with picture carriers spaced 6 Mhz apart and beginning at 4.45 Mhz are described in the second CIP application. Also, a picture carrier of 4.45 Mhz is above the minimum frequency requirement of 4.25 Mhz suggested above.

Amplitude modulation is particularly adequate when only a small number of signals transmit over a short distance. As transmission distance increases, attenuation causes the SNR at the receiving end to drop. Similarly, as more channels are added to a wire pair of fixed length, one is forced to use higher frequencies, until the signal at the highest frequency is not received with an adequate SNR. (Note that capacity tightens up very rapidly with increasing frequencies because attenuation increases and at the same time the signals radiate more, forcing a reduction in the initial signal levels.)

A third phenomenon that can cause an inadequate received SNR is the presence of broadcast energy, which elevates the noise level. This is largely a function of the radio broadcasters in the area, but it is also related to frequency because telephone wiring acts as a more efficient antenna as the frequency of the broadcast signal increases.

5a) Increasing Bandwidth to Counter Signal Attenuation

When the attenuation of transmission or the presence of broadcast energy at the "unused" frequencies on a transmission line suppresses the SNR at the receive end below the minimum required for AM video, the proposed solution is to use frequency modulation with bandwidths significantly larger than 4 Mhz. (Four Mhz is the approximate bandwidth of an NTSC video signal at baseband.) As mentioned in the first CIP application, receivers in FM communication systems that use 15 Mhz of bandwidth per NTSC video signal are known to produce a demodulated signal that is approximately 10 db higher than the SNR at its input. This is an improvement over AM systems because, in those systems, the SNR at the receiver output is equal to the SNR at the receiver input.

Following is an example. Assume that nine AM NTSC signals transmit across a path 400 feet long within adjacent 6 Mhz channels beginning at 6–12 Mhz and ending at 54–60 Mhz. Now assume that a signal of 45 dB mV with a carrier